



NEW BIOLOGY

SMALLWOOD · REVELEY · BAILEY

CURRICULUM

#1278

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS



570.1

S

407H

R. Davis

126

Jean Blackie
Riverview
Sask

Grade XII

Simonne Tremblay.

Madys





Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

<https://archive.org/details/newbiology00smal>

47. 97. 129. 170

Marion Bell.
2167 Cornwall St.
Regina Sask.

Central Collegiate
47



There with a light and easy motion,
The fan-coral sweeps through the clear, deep sea,
And life, in rare and beautiful forms.
Is sporting amid those bowers of stone.

— J. G. PERCIVAL

NEW BIOLOGY

BY

W. M. SMALLWOOD

SYRACUSE UNIVERSITY

IDA L. REVELEY

WELLS COLLEGE

GUY A. BAILEY

GENESEO STATE NORMAL SCHOOL



ALLYN AND BACON

BOSTON
ATLANTA

NEW YORK
SAN FRANCISCO

CHICAGO
DALLAS

456.

COPYRIGHT, 1934
BY ALLYN AND BACON

FTF

△

LIBRARY OF THE UNIVERSITY
OF ALBERTA

PREFACE

New Biology is a new book in every way. New subject matter, new organization, hundreds of new pictures, new teaching aids, and numerous other new features speak for themselves. On the other hand, the authors have continued from earlier editions those basic principles of good exposition and classroom method which have proved so popular.

The authors have worked to make *New Biology* a vital, human biology. At every turn they have sought the point of view of the young pupil who is dynamic, alert, keenly interested in life and living things. They have written about the everyday world, the world that young people know and can enjoy when it is made meaningful and natural. They have measured and weighed objectives, retaining only those that are practical and significant in terms of modern needs:

The scientific attitude and scientific method, avoiding abstruse verbiage, dominate the presentation of materials. Simplicity of statement and appropriateness of subject matter are keynote characteristics.

An important consideration which has received careful attention is the need of encouraging the pupil to be independent in his study. Laboratory exercises, new objective tests, full-page summary diagrams of life processes, and pertinent pictures closely correlated with the subject matter are all designed to create a maximum of pupil activity with a minimum of direction by the teacher. The attitudes, habits, and skills of the true scientist cannot be inculcated in any other way. Biology is the perfect science for the realization of this objective.

New discoveries, new concepts, new investigations, belong to the program of the progressive scientist. *New Biology* is up-to-date in its treatment of these. Yet it recognizes the value

of historical background and includes colorful biographies of scientific men. Here the human touch gives impetus to the pupil's understanding of science as a living subject, highly important to human welfare. In this way the pupil is constantly stimulated to act as a scientist, to observe, explore, experiment, discover, and apply the fascinating facts of biology for himself.

Special attention has been given to human biology and public health and to those personal factors which control mental health. In keeping with this objective there is a new chapter dealing with the vocational applications of biology, particularly with reference to preparation for specialization in professional vocations. There is an attractive section dealing with the rich possibilities of biology as an avocational subject.

The authors acknowledge here, with grateful appreciation, the helpful suggestions submitted by the many teachers who have used preceding editions. They are indebted to Dr. Carleton F. Potter for the X-ray illustrations, to the United States Department of Agriculture, the American Museum of Natural History, the New York State Conservation Commission, the Geneva Agricultural Experiment Station, to Veronica E. Corrington, and to many friends, who have furnished illustrations that add much to the book. The color plate of butterflies was taken from the plates issued by The Butterfly Box, Incorporated, of Boston.

W. M. SMALLWOOD
IDA L. REVELEY
GUY A. BAILEY

TABLE OF CONTENTS

UNIT I: PRINCIPLES OF BIOLOGY

CHAPTER	PAGE
 I. THE LIFE OF THE APPLE TREE	1
II. IMPORTANT LIFE FUNCTIONS	15
III. COMPOSITION OF LIVING THINGS	23
IV. THE GREEN PLANT AS A FOOD FACTORY	38
V. THE PHYSICAL BASIS OF LIFE	46
TEST I	51

UNIT II: THE BIOLOGY OF ANIMAL LIFE

VI. THE GRASSHOPPER, A TYPICAL INSECT	53
VII. THE STUDY OF INSECTS AND THEIR HABITS	65
VIII. MOTHS, BEES, AND ANTS	90
IX. CRAYFISH	104
X. SOME OTHER INTERESTING INVERTEBRATES	113
XI. A SIMPLE VERTEBRATE, THE FISH	124
XII. SALAMANDERS, FROGS, AND TOADS	140
XIII. THE REPTILE GROUP	155
XIV. BIRDS	161
XV. MAMMALS, THE RULERS OF THE EARTH	188
TEST II	211

UNIT III: THE BIOLOGY OF PLANT LIFE

XVI. INTRODUCTION TO THE FLOWERING PLANTS	215
XVII. LEAVES — THE PLANT'S FACTORY	218
XVIII. THE STEM — THE PLANT'S SUPPORT AND ORGAN OF CIRCULATION	235
XIX. THE ROOT — THE PLANT'S ABSORBING ORGAN AND ANCHOR	249
XX. FLOWERS AND FRUITS	257
XXI. THE SEED — HOW A FLOWERING PLANT BEGINS LIFE	282

CHAPTER	PAGE
XXII. FORESTS AND FORESTRY	291
XXIII. FERNS AND FERN-LIKE PLANTS	309
XXIV. A GLANCE AT THE SIMPLEST ORGANISMS	322
XXV. BACTERIA — THE SMALLEST AND SIMPLEST PLANTS	338
XXVI. ANIMALS AND PLANTS OF THE PAST AND FUTURE	362
XXVII. HEREDITY AND VARIATION	376
TEST III	396

UNIT IV: THE BIOLOGY OF THE HUMAN BODY

XXVIII. AN INTRODUCTION TO HUMAN BIOLOGY	400
XXIX. THE COVERING OF THE BODY	417
XXX. WORK AND PROTECTION	425
XXXI. TRANSPORTATION SYSTEM	441
XXXII. SUPPLY AND DEMAND	458
XXXIII. THE REGULATING MECHANISMS	482
XXXIV. THE BEGINNING AND THE END	502
XXXV. SOME BIOLOGICAL PROBLEMS THAT MAN TRIES TO SOLVE	506
XXXVI. HABIT-FORMING DRUGS AND TOBACCO	531
XXXVII. BIOLOGY AND VOCATIONS	545
TEST IV	561

APPENDIX

CLASSIFICATION OF ANIMALS AND PLANTS	567
BIBLIOGRAPHY	570
GLOSSARY	573
INDEX	1

PORTRAITS OF PROMINENT BIOLOGISTS

	FACING PAGE
MATTHIAS JAKOB SCHLEIDEN AND THEODOR SCHWANN	48
MARCELLO MALPIGHI	49
JEAN HENRI FABRE	56
L. O. HOWARD	66
JESSE LAZEAR	84
JOHN HENRY COMSTOCK	94
LORENZO LORRAINE LANGSTROTH	95
THOMAS HENRY HUXLEY	108
CHARLES WARDELL STILES	120
DAVID STARR JORDAN	126
LOUIS JOHN RUDOLPH AGASSIZ	142
FRANK M. CHAPMAN	162
JOHN JAMES AUDUBON	170
LOUIS AGASSIZ FUERTES	171
CHARLES EDWIN BESSEY	260
ASA GRAY	261
CHARLES DARWIN	324
LOUIS PASTEUR	344
ANTONY VAN LEEUWENHOEK	345
ROBERT KOCH	346
HENRY FAIRFIELD OSBORN	372
LUTHER BURBANK	373
GREGOR JOHANN MENDEL	382
THOMAS HUNT MORGAN	383
WILLIAM HARVEY	442
JOSEPH GOLDBERGER	476
THEOBALD SMITH	520
W. T. SEDGWICK	526
SIR JOSEPH LISTER	527

COLOR PLATES

TROPICAL FISHES	<i>Frontispiece</i>
	FACING PAGE
BUTTERFLIES	92
REDHEADED WOODPECKER	176
RED FOXES	190
WILD MOCCASIN FLOWERS	272
THE CIRCULATION OF THE BLOOD IN MAN	446
"LIKE LIVING COALS THE APPLES BURNED"	560

NEW BIOLOGY

UNIT I: PRINCIPLES OF BIOLOGY

CHAPTER I

THE LIFE OF THE APPLE TREE

Fragrant blossoms fringe the apple boughs.

— WELBY

1. What Is Biology? — Biology is the study of living things — plants and animals. This study will show us: (1) how these things live; (2) their relations to one another; (3) how they depend on the physical world about them; and (4) man's power to control them.

We can illustrate much that we wish to know by studying the life of something we are all familiar with, for instance, an apple tree.

2. The Apple Seed and Its Seed-Leaves. — When the seed of an apple sprouts, a tiny plant comes through the ground bearing two green seed-leaves. There is a little stem that joins the leaves and there are small roots that reach down into the ground. In a few days two more leaves appear. These are thinner and of a deeper green color than the seed-leaves.

3. The Roots and the Soil. — Our little seed has now developed into a

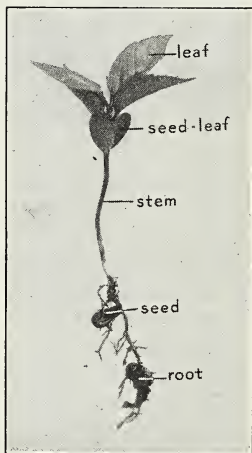


FIGURE 1. A VERY YOUNG
APPLE TREE

In which parts do you think the most change will take place?

plant. It has all the parts that a small plant needs. The roots take up food in the form of solutions, that is, water in which parts of the soil are dissolved. These roots must grow in soil, for they cannot live if they are exposed to the sunlight. The soil must be of the right kind if the plant is to grow well and there must



FIGURE 2. A DAMAGED APPLE LEAF

A recently imported insect, the "skeletonizer," injured this leaf.

starch that are in the stem and the sugar that is in the apple, as well as the material of the leaves themselves, are all made by the thin green leaf.

The leaf does this work in spite of many annoyances; at least we should call them annoyances if we were leaves and they happened to us. The worst annoyances are the insects that like to feed upon the leaves. One of the insects which likes apple leaves is called the *gallfly*. It lays its eggs on the leaves, and these hatch into tiny worm-like creatures, which so irritate the leaves that they grow little coverings called *galls* around the gallflies. Instead of harming the gallflies, how-

be considerable water in the soil to dissolve solid parts for the root to absorb.

As the seedling develops, it sends out more roots. These branch and subdivide till they take up about as much space in the ground as the branches do in the air. If we could take a tree from the ground and not break off any roots, it would be somewhat like a dumbbell, with the hand grasping the stem and at either end a cluster of branching parts.

4. The Leaf and the Gallfly.—The leaf is the principal factory of the tree. With the help of the sun it takes the water that comes up through the trunk from the root and combines it with some parts of the air so as to manufacture nearly all the material that the plant uses. The wood and

ever, the galls afford them food and shelter so that even the sharp-eyed birds cannot find them.

There are a hundred other kinds of insects, like the leaf-cutting bee and the gypsy moth, that feed upon the leaves of apple trees. Of course, the leaf is not able to do its work well when it is weakened by the attacks of these insects.

5. The Stem and the Borer. — The leaves, the branches, and the fruit are all supported by the stem, or *trunk*, of the apple tree, and its strength keeps pace, as a rule, with the growing burden it has to bear. It also provides passages for carrying materials from the roots to the leaves and for taking other materials from the leaves back into the roots. Besides this, the trunk is used for storing food. It contains the starch which the leaves have manufactured. This is food for some animals.

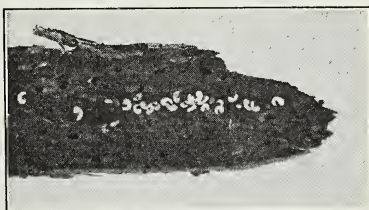


FIGURE 3. APPLE TREE BORERS IN THE LARVAL STAGE

The borers are living beneath the bark and are choice food for the downy woodpecker.

One of the insects which gnaws its way into the trunk of the tree is the *borer*. It gets food from the parts it gnaws away and at the same time is hidden from the birds that might otherwise feed upon it. When many borers eat their way through a trunk, it is so weakened that it cannot do its work and the tree breaks off and crashes to the ground. Thus, the stem, like the leaf, is not able to do its work properly if it is attacked by insects.

6. The Root and the Grub. — Roots grow wherever there is food for them in the soil. Where food is abundant, they are numerous, but where the soil is poor, they do not develop. Strong, numerous roots tend to produce a heavy, thick trunk, which in turn is likely to support strong, vigorous branches and leaves.

Roots hunt out the water in the soil and sometimes develop a large root system especially for the purpose of taking up water.

Such a root system may force its way into a water pipe if the root can find a break.

The woody materials of which roots are composed are good food for some animals (grubs) that burrow in the soil. Certain insects lay their eggs in the branches of trees, and when the young hatch, they burrow through the stems, causing them to die and drop off, the young insects falling with them. When the twigs dry up,



FIGURE 4. APPLE TREES IN BLOSSOM

To understand the biology of the apple tree, you must make a careful study of the tree during blossom time. What insects visit these blossoms? Do all of the blossoms become apples?

the young insects leave them, burrow into the ground, and feed upon the roots there. The root, like the leaf and the stem, cannot function properly under these conditions.

7. The Blossom and the Bee. — After an apple tree is seven or eight years old and has a well-developed root system, a fairly strong trunk, and a good showing of branches, it usually begins to blossom. A blossom is the first step in the production of fruit.

There are several parts in the blossom: (1) the small leaf-like parts (*petals*), the pinkish white color of which serves to attract

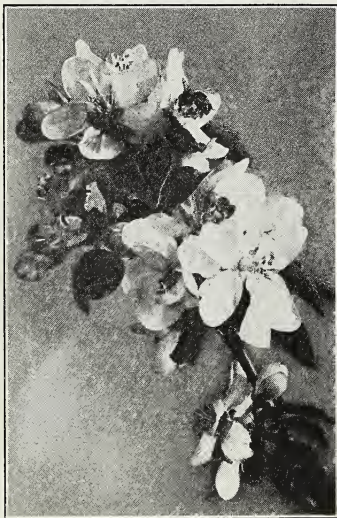
the attention of insects; (2) a sweet fluid (*nectar*); (3) numerous minute *stamens* that produce a yellow dust (*pollen*).

The chief use of the nectar is to attract bees, which use it to make honey. Bees visit many blossoms before they have all the nectar they can carry, and in going from one blossom to another they carry pollen. This pollen is necessary to the proper fruiting of the plant. The bee, therefore, renders a real service to the apple tree, for without this transfer of pollen from one blossom to another (*cross-pollination*) very few apples would form. In this case we have an insect that is not an enemy to the tree but a most necessary friend. The blossom is able to do its work much better because it has insect friends which use it for their own advantage and in so doing render a service to the tree.

8. The Fruit and the Life Cycle.

— If the bee has done its work well and the weather is favorable, the base of the flower develops into the fruit

with seeds inside. While it is young, the apple is green like the leaves. It does not show color until it begins to form sugar, which makes it edible. We might say that the apple is advertising its sweetness, so that some animal will eat it. As the core contains the seeds, these may then find a favorable place to grow and may, in time, form new plants. This brings us back to our starting point; the tree has completed its life cycle.



U. S. Department of Agriculture

FIGURE 5. BEES ON APPLE BLOSSOMS

Why do bees visit these flowers? Is the visit beneficial?

9. The Story of the Codling Moth. — Not only is the apple eaten by large animals, but it is also food for small animals that live inside it for a time. They eat it and at the same time use it for a shelter and as a protection from their enemies.



FIGURE 6. HARVESTING THE APPLE CROP

The “worm” so often seen in apples (Figure 8) is the young of the *codling moth*. This “worm” is called a *larva*. The larva hatches from the egg which the moth laid just as the little fruit began to form. The larva bores its way into the core, eats and grows, and sheds its skin (*molts*) three times until it is full grown. Then it bores its way through the side of the apple and finds some protected spot, usually under the bark of the tree,

where it spins a silk-like nest (*cocoon*) around itself.

After staying in the cocoon for a time, it sheds its skin for the fourth time, but now we have not a larger larva as in previous molts, but a new stage in the life of the codling moth. This is called a *pupa*. In this pupa stage, it can take no food, for it has no mouth parts and it cannot move about, for it has neither legs nor wings. But it can wiggle and can take in air through the

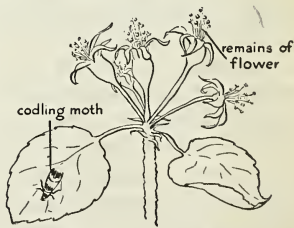


FIGURE 7. THE CODLING MOTH

After the eggs laid by the codling moth hatch, the young crawl to the blossom and begin their growth.

openings in the sides of its body. The length of time it remains in the pupa state depends on the temperature. Finally, the fifth molt occurs, the adult moth emerges from the pupa, and in a few days the females are ready to lay eggs in favorable places. This brings us back to our starting point, and we may say the codling moth has completed its life cycle.

10. The Last Chapter in the Story of the Apple Tree.

—The mature apple tree bears fruit for many years. But insects continue to infest it until finally some of its branches decay and holes are formed in them. As

time goes on the branches weaken and the winds break off many of them. Decay progresses and eventually the tree weakens and falls. The wood is probably saved by the owner, who cuts it up into firewood and burns it.

In this way the work that the leaves did during years of patient labor is being rapidly undone by the flame. The substance that the leaves took from the air is going up the chimney and returning to the air in the form in which the leaves received it. This substance is a gas called *carbon dioxide*. The water that the leaves received through the trunk, which in turn was taken from the soil by the rootlets, is also going up the chimney in the form of water vapor to be returned to the earth again when it has been condensed into rain. The mineral substances that the rootlets took from the soil in solution are found in the ashes.

Thus one might say that the elements involved in these processes have "completed their cycle." For example, the carbon which forms a part of the gas, carbon dioxide, was combined with other elements to make the starch in the leaves. This was converted into wood and served for a time in the trunk or branch or root until the tree was burned. Through the action of the flame, the wood was changed for a time back to carbon; then further

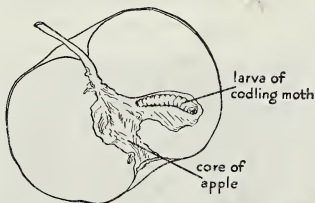


FIGURE 8. CODLING MOTH LARVA

What does this "worm" eat?

action of the flame joined the carbon and oxygen and it went up the chimney as carbon dioxide. All of the carbon, oxygen, and other materials of this tree are now in the air and soil, where the young apple tree found them.

After the trunk and limbs have been cut into firewood, a short stump is left. In this, slow changes take place like those brought

about rapidly when the wood was burned. This slow decay begins (Figure 9) when the stump is attacked by the elements and by tiny plants, called *bacteria*.

Eventually the wood in the stump becomes soft and crumbles. In these changes all of the carbon, oxygen, and other materials locked up in the stump are released and returned to the air and



FIGURE 9. THE FALLEN APPLE TREE

What changes are taking place?

soil. This would have happened to the entire tree, if man had not taken the wood to burn.

The apple tree, then, uses oxygen, carbon, water, and other substances in order that it may live. The codling moth does the same thing, but it obtains its food by eating the apple. When the codling moth dies, it decays like the stump and the materials in its body break up by similar processes.

11. Budding and Grafting. — Apples grown from seed are called “native fruit,” and are usually small and sour and wholly undesirable as human food. Man has found this out and he knows how to avoid it. When the tree is small he cuts a leaf bud from an apple tree that he knows to be good, for instance, a Baldwin. This he places in a slit in the bark of a seedling (Figure 10). This is called *budding*. If he is careful, this bud will live and unite with the stock upon which he has budded it. Then all the rest of the tree above the bud is cut off and he has a tree bearing only one kind of fruit. In nurseries thousands of these little

seedlings a year or two old are budded to produce well-known varieties. These are then distributed to fruit growers throughout the country. The favorite apples have names to distinguish them in the market. Some of the best known are the Baldwin, greening, northern spy, delicious, winesap, McIntosh red, wealthy, and Spitzenburg.

Another way in which fruit may be changed is called *grafting*. We take small branches of the desired tree and cut them wedge-shaped. Then we saw off a branch from the tree to be grafted, split the end that remains on the tree, and set our little branch in this wedge-shaped opening. If the cut parts are covered with grafting

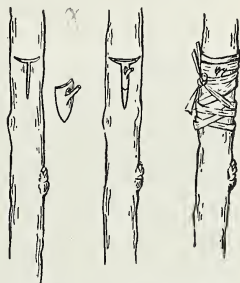


FIGURE 10. STEPS IN BUD GRAFTING

wax to keep out the water and prevent decay, the little branch will grow and bear apples like the tree from which it was cut. Many kinds of apples can be grafted on one tree so that one may pick early apples and late apples from the same tree.

This is possible, but impractical. (See Figure 11.)

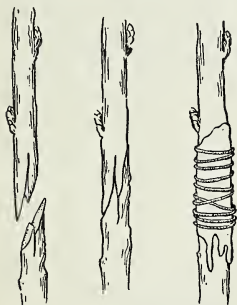


FIGURE 11. STEM GRAFTING

12. New Varieties. Cross-Pollination. — Experimental fruit growers are constantly seeking to improve the kinds of apples that are popular. Some apples have unusual flavors that are well liked but they do not ship well because they are tender and will not stand the jar and shaking of transportation. It is necessary to *cross-pollinate* in order to get new varieties.

By this we mean taking the pollen from the blossom of one variety of apple tree and putting it on the productive part (*stigma*) of a blossom of another variety. By so doing we try to combine the desirable qualities of both kinds

of apples. Nearly all states have experiment stations where this work is carried on.

Not all the apples that are popular today have been developed by the hand of man acting as a pollinator. Most of the well-known varieties of today are the results of chance seedlings. This is true of the three most popular eastern apples, the Rhode Island greening, the Baldwin, and the northern spy.



FIGURE 12. WILD AND CULTIVATED APPLES

The two small apples show the size of the wild apples of Europe and Asia from which most improved varieties have been derived.

The larger one, a northern spy, is shown for comparison.

The Story of the Northern Spy. — This apple appeared in an orchard of seedlings that was planted by Heman Chapin in East Bloomfield, near Rochester, New York. The seedlings came from seeds that were brought from Salisbury, Connecticut, to East Bloomfield about the year 1800.

Sprouts from the original tree were taken up and planted by Roswell Humphrey and by him the first fruit of the northern spy was raised as the original tree died before bearing. In 1847 nine of the trees set out by Humphrey were still living. The variety was confined to the vicinity of its origin for many years and it was not till about 1840 that it began to attract the attention of fruit growers in other localities. Its great value then came to be more widely recognized and in 1852 the American Pomological Society listed it not only as a new variety of promise but also as a variety worthy of general cultivation. Since that time it has become extensively planted not only in New York but in various other portions of the more northern apple-growing regions.

— Beech, *The Apples of New York*

The northern spy has been so extensively planted and the fruit has proved so popular that a monument has been placed on the site of the orchard where the original tree was planted.

In Washington and Oregon the Spitzenburg, delicious, Jonathan, and Rome beauty are superior varieties. Many of these fine apples reach the eastern markets and are sold by the piece at fruit stands in competition with oranges and bananas. In the

mid-west the same apples are popular, while farther south the winesap, the Stayman, and the York imperial are the leading varieties.

Where Apples Originated. — All the various kinds of apples in the United States may have come from the wild apples of Europe. By selection larger and better apples were cultivated until several superior ones were sent to the various countries. Probably the Hollanders brought the first apples to the early colonies in America.

13. Man and His Competitors. — We have mentioned the enemies of the leaf, stem, root, and fruit. Man must match his wit against these competitors if he is to secure a large crop of apples. He uses a poison spray which kills the larvæ and other enemies of the leaf. At the time the young fruit is forming, another kind of poison spray is put on the tree to kill the small larvæ that would enter the apple. Other enemies of man and the apple attack the buds before they have developed and these must be subdued by a poison spray. Even after the apples are picked and stored, there is danger of injury to them by insect enemies. These are held in check by putting the apples in cold storage, which prevents the insects from doing further damage.

14. Biology Defined. — We have now seen through our study of the apple tree and its various friends and enemies just what we outlined in the opening paragraph of the book. We have noted (1) how apple trees live, (2) how they are related to insects, (3) how they depend on the physical world about them, and

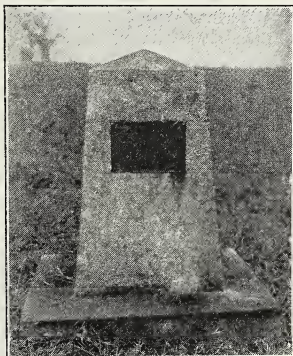


FIGURE 13. MONUMENT TO THE NORTHERN SPY

The plate reads, "The original northern spy apple tree stood about 14 rods south of this spot, in a seedling orchard planted by Heman Chapin about 1800. The Early Joe and Melon apple also originated in this orchard."

(4) how man can control them. These are the four central ideas in our study of biology.

Biology is the science that tells how animals and plants live. No kind of plant or animal is able to live without building up its body, providing for more plants or animals like itself, and finally breaking up into the very materials that originally united to form the substance of its body.

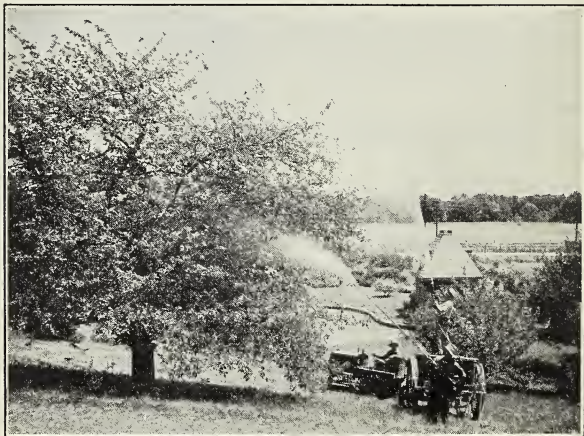


FIGURE 14. A MODERN POWER SPRAYER

Why is the use of this sprayer necessary?

PROJECT

Can you find any wild apples? How many wild fruits exist near your home? Select some animal or plant in the garden, park, field, or woods and make a special study of it and its relation to water, air, soil, food, and man. How fast does it grow? How old is it? What happens during the winter, spring, and summer? Follow the plan we have used in studying the apple tree, and record your observations. These results should be written up and reported to the class from time to time during the year. At the end of the year, the observations which each one has been making should be turned in. In this way much interesting biological information about the living things in your immediate community will be collected.

SUMMARY

Biology is the study of living things. Plants and animals are necessary to man's very existence on the earth. In studying them we learn their relations with one another and with the world about them, and how we can control them.

We chose the apple tree for this study because it is so familiar. We saw how the seed sprouts, and how the plant sends its roots into the ground and its stem into the air to put forth leaves, blossoms, and finally fruit. In the fruit is the seed, which starts the life cycle again.

During this growth we see how the apple tree has a constant struggle with various insects and how man helps it in this fight by spraying it. Man also controls the fruit by budding, grafting, and cross-pollination. In this way we see the four central ideas of biology: (1) how things live; (2) how they are related to one another; (3) how they are related to the world about them; and (4) how man controls them.

QUESTIONS

Define biology. What are its four central ideas? How is each of these illustrated in the story of the apple tree? What is the chief function of the root? of the leaf? of the stem? Name an enemy of the root; of the leaf; of the stem; of the fruit. What insect is helpful to the apple tree? What do we mean by *life cycle*? Describe the life cycle of the apple tree. In what ways does man control the enemies of the apple tree? In what three ways does man control the kind of fruit?

SPECIAL TOPICS FOR DISCUSSION

1. How many kinds of apples do you know?
2. In what states are they produced?
3. What is the difference between a fall apple and a winter apple?
4. Does your state produce more apples than it can use? If it does, what use is made of the surplus? If your state does not raise as many apples as it consumes, where does it secure apples?
5. What are some of the reasons why apples are raised in certain regions only?
6. What are some of the difficulties that have to be overcome in raising apples that will sell on fruit stands?
7. What is the grading of apples?
8. Apples are exported to Europe. Can you offer an explanation of why this is true?
9. What methods are used in preparing apples for such long transportation?
10. Would an importer have a right to raise this question: What sprays were used?

COMPLETION TEST

On a separate piece of paper, list the numbers of the following sentences and opposite these numbers place the word from the right-hand column which makes the statement correct. *Do not mark your book.*

- | | |
|---|-------------|
| 1. Biology is the study of ____ things. | control |
| 2. Roots take up food in the form of ____. | living |
| 3. The very young apple tree is called a ____. | wit |
| 4. The ____ is the principal factory of the tree. | grub |
| 5. The ____ injures the leaves of the tree. | larva |
| 6. The ____ injures the trunk of the tree. | solutions |
| 7. The ____ injures the roots of the tree. | pollination |
| 8. The ____ carries pollen from one blossom to another. | borer |
| 9. The sweet fluid in the apple blossom is ____. | gallfly |
| 10. The transfer of pollen from the stamen to the pistil is ____. | pupa |
| 11. The codling moth lays its ____ in the apple blossom as | seedling |
| the petals begin to fall. | eggs |
| 12. The ____ is the destructive stage of the codling moth. | insects |
| 13. The larva of the codling moth ____. | honey bee |
| 14. The resting stage of the codling moth is called a ____. | Hollanders |
| 15. The decay of the old apple tree is caused by ____. | leaf |
| 16. We are able to control the kind of fruit that an apple tree | budding |
| bears by grafting or ____. | nectar |
| 17. Probably apples were brought to America by the ____. | molts |
| 18. Man must match his ____ against the other animals and | bacteria |
| plants that attack his apple trees. | |
| 19. Cold storage checks the injury by ____ after the apple | |
| crop is picked. | |
| 20. Man progresses in culture as he learns to ____ his en- | |
| vironment. | |

REFERENCES

- Gager, *Fundamentals of Botany*, Chapter XI, Blakiston's Son and Company
 Sinnott, *Botany, Principles and Problems*, pages 17-20, 23-35, McGraw-Hill
 Publishing Company
 Transeau, *General Botany*, Chapter II, World Book Company
Apple Insects and Their Control, Bulletin No. 475, New York Agricultural
 Experiment Station, Geneva, N. Y.

CHAPTER II

IMPORTANT LIFE FUNCTIONS

*How many lives we live in one,
And how much less than one, in all!*

— ALICE CARY

15. What Life Functions Are. — We have just learned something about the way the apple tree lives. As we study other plants and animals and how they live, we shall see that all of them have several functions in common. These are called *life functions*. It is a common mistake to think of these processes as separate or distinct, when they are really closely dependent one on another. These life functions are: sensation (irritability), motion, food-taking, nutrition (digestion, absorption, circulation, assimilation), respiration, excretion, and reproduction.

Sensation (Irritability). — Animals are sensitive to heat, light, and other outside influences which we call *stimuli*. Plants, too, respond to light, heat, and other stimuli. This reaction or response of animals and plants to stimuli is called *sensation* or *irritability* and is an important life process, for it enables them to act so as to profit from their surroundings. In other words, sensation enables animals and plants to adapt themselves to their environment.

Motion. — All animals can move from place to place or move parts of their bodies. The higher animals move with ease as a result of highly developed muscular and nervous systems. The lower animals are more limited in their movements. Tiny plants move about in the water, and the leaves of many higher plants move toward the sunlight. Life movement then in animals and plants is not, like the moving of the wind or of a flowing stream, purely physical motion, for a living thing has to supply from its

own body the energy required for motion. Living things can change at will the direction and speed of their movements, but lifeless physical forces cannot. In biology *motion* is defined as the ability of living things to change their position without employing the force of the wind, or gravity, or similar outside agencies.

Food-Taking. — If we live normal lives, we eat regularly, in the morning, at noon, and again at night. We feed our pets

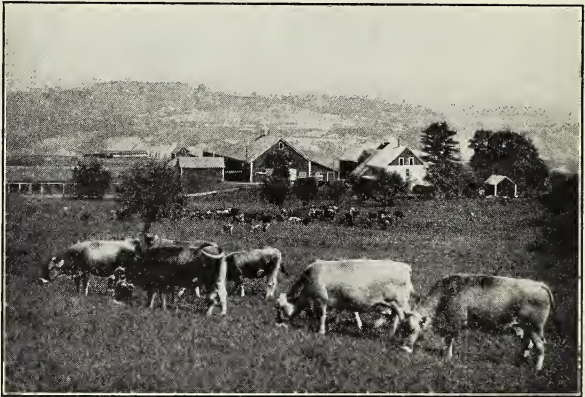


FIGURE 15. A SOURCE OF FOOD FOR THE COW

How does this help man?

regularly, if we have any. The farmer has to feed his cattle, horses, and sheep when they are confined in the stables. In summer, when they are turned out to pasture, they secure their own food and eat at irregular intervals. The fox hunts at night or early morning and captures mice or occasionally steals a chicken. All this illustrates another life function, *food-taking*.

There are a few plants, like the Venus's-flytrap, that can capture insects and use their bodies as food. But this is not usual with plants. Food-taking is really true only of animals, for the green plants manufacture their own food, chiefly in their leaves.

Nutrition. — Nutrition includes first the preparation of food so that the animal or plant may have it in the form of a solution (liquid). This is *digestion*. Next, the food must be taken into the veins of the animal or plant. This is *absorption*. Then the food must be carried to all parts of the animal or plant. This is *circulation*. And lastly, each part of the animal or plant must take from the blood or the sap the food that it needs and build it into protoplasm.¹ This is *assimilation*. *Nutrition* is the term under which are described the changes in food from the time it enters into solution until it becomes a part of the living body of an animal or plant.

Respiration. — All animals and plants require energy in order to live. When oxygen unites with the protoplasm of the cells, energy in the form of heat is produced. Two waste products result, carbon dioxide and water. Respiration is the introduction of oxygen into the cells, the production of heat, and the giving off of carbon dioxide. Respiration, which takes place in every living cell, should not be confused with breathing. Only animals that have lungs can breathe. Breathing is merely the bringing of oxygen from the air in contact with the blood vessels of the lungs. Animals that do not have lungs and plants have other structures for admitting oxygen to the living cells.

Excretion. — In the section on respiration the gas, carbon dioxide, was named as a product of respiration. Carbon dioxide is a waste product of respiration made up of carbon and oxygen, and is removed from the bodies of higher animals through the lungs and skin. It may pass directly into the air from the leaf of a plant or through the skin of an earthworm. The manifold activities of living things result in the production of other waste products. To an animal or plant a worthless or waste product is one that does not yield it energy. *Excretion* is the elimination of waste products from the bodies of animals and plants.

The foregoing life processes have to do with the life of the

¹ The word *protoplasm* comes from two Greek words meaning *first form*. It is the original, simple material of which the cells (see page 46) of plants and animals are made up.

animal or the plant itself. There is another life process by which individuals keep alive the races of animals and plants, namely, reproduction.

Reproduction. — All kinds of animals and plants either produce young or become extinct. It is common knowledge that all living things grow old and eventually die, and if there were no provision for producing young, there would be no such thing as continuing life. While the bodies of animals and plants are young, nature gives them the means and the instinct to produce more animals and plants like themselves. This has been the story since the beginning of life so far as science can determine, and it is the only means by which there can be any increase in the total number of living things. *Reproduction*, then, is the process by which life continues from generation to generation.



FIGURE 16. A SQUIRREL

What adaptations does this pose show?

16. Adaptation. — Adaptation shows how the animal or plant

responds to outside conditions. There are countless examples of adaptation. Squirrels are a good illustration. Their toes are provided with sharp, curved nails that make it easy for them to hold fast to the rough bark of the tree, and when they jump from branch to branch, the tail acts as a rudder.

If a squirrel has more nuts than he can eat at once, he buries some of them in the earth. In doing this he uses his front feet for digging a hole in the ground, while he holds the nut in his mouth. Name three different ways in which the squirrel uses his front feet.

When you use a fountain pen, notice in what ways your hand shows adaptations useful for handling this instrument. First,

you take it from your pocket. Then you take the cap from the pen with one hand, while you hold it with the other. You place the cap on the top of the pen, the fingers exerting just the right pressure in removing it and forcing it on the pen. Taking the pen in your right hand, you begin to write. The pen point is moved in the proper direction to make letters, forming accurate loops and curves because the hand has been trained to make these

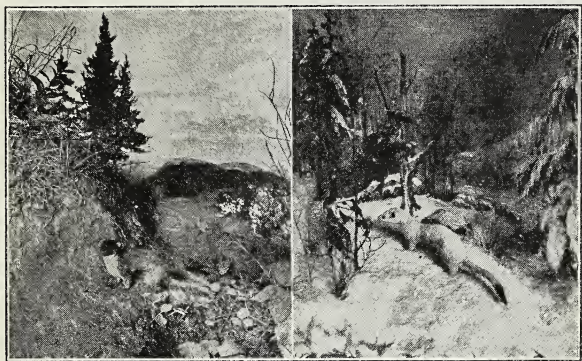


FIGURE 17. A WEASEL IN SPRING AND IN WINTER
What kind of adaptation do these pictures illustrate?

lines as you wish. It has become especially adapted to do this work. In all this the thumb plays such an important part that man is sometimes called the "thumbed animal."

The various shapes of our teeth permit us to eat a great variety of food. In front are the chisel-shaped teeth for cutting; then come the tearing teeth on each side; these in turn are followed by broad crown teeth that crush and grind the food. Most fishes, frogs, and alligators have all their teeth conical in shape. Teeth of this shape serve only to hold the captured prey from escaping or to tear the flesh. The teeth of such animals do not show as much adaptation as those of man. (See § 351 and diagram.)

The elephant is a familiar and very good example of adaptation. His two tusks, often several feet long, are really overgrown teeth and are used for defense. The trunk of the elephant is another unique adaptation. It is really the nostrils and upper lip greatly drawn out, and is used in browsing and in drinking, because his huge bulk and short neck prevent him from reaching down to graze or to drink. (See Figure 191, page 201.)



FIGURE 18. A PRAYING MANTIS RESTING ON A MILKWEED POD

Name the adaptations shown by the milkweed seeds and by the insect resting on the pod.

Have you ever seen the seeds of the maple tree that grow large wing-like vanes on the sides? This is an adaptation that enables the wind to carry the seeds away from the parent tree and thus give them a better chance to grow. The milkweed seed has downy tufts and the dandelion seed tiny plumes that carry them miles away from the place where the parent plants grew.

Many plants have special adaptations that help them to climb; for example, the tendrils of the common pea and grapevine.

The coconut has a buoyant husk that allows it to float down rivers and in the currents of the ocean perhaps a hundred miles, till the waves carry it up on the shore, where it grows into a coconut tree. Some plants, like the wild geranium, hold the seeds by a spring that throws them several feet when released. All these are adaptations that plants employ in distributing their seeds.

The main adaptations of animals are: (1) *those that assist in food-getting*, as the teeth of the squirrel or the sharp curved beak of the hawk or eagle (see Figure 19); (2) *those that aid in self-*

protection, such as the legs of the rapid running deer, the color of a moth, the fins of the fish for moving through the water, the wings of the bird for flying through the air, or the resemblance to a twig or leaf, as the praying mantis (Figure 18).

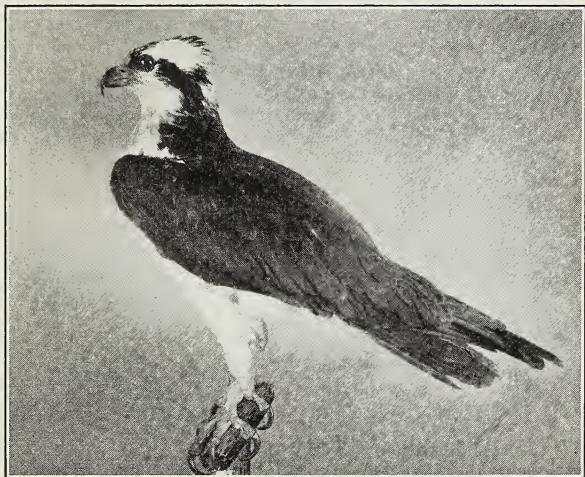


FIGURE 19. AN OSPREY

Notice the adaptations shown in this bird's beak and claws.

SUMMARY

All living things have certain life processes or functions in common. Two of these, sensation and motion, may seem at first less vital than respiration, food-taking, nutrition, excretion, and reproduction, but really all are essential, for without the power to feel and to move the other processes could not be carried on.

These functions have to do with the life of the plant or animal itself; reproduction continues that life from generation to generation. Adaptation is not a life process, but it is a very important phase of life, for everything in life is adapted in one way or another to the work it has to perform. Thus we see in the paws, teeth, and tail of the squirrel, in the human hand, and even in the wings of some seeds, adaptations to help the animal or

plant to live. Most adaptations are for food-getting, for protection, or for adjusting the plant or animal to its surroundings.

QUESTIONS

What are the life processes or functions? Do some seem more important than others? Are they in reality more important? What are the four processes of nutrition? Is reproduction a life process? Is adaptation? What adaptations has the squirrel for food-taking? for motion? What special adaptations has the human hand for the enormous variety of things it can do? Give other examples of adaptation in plants and animals. What are the three main objects of the various adaptations of plants and animals?

REFERENCES

Coulter, *Plant Relations*, Chapter I, D. Appleton and Company
Smallwood, *Man — The Animal*, Chapter XI, The Macmillan Company
Woodruff, *Foundations of Biology*, Chapter I, The Macmillan Company

CHAPTER III

COMPOSITION OF LIVING THINGS

*All the means of action —
The shapeless masses, the materials —
Lie everywhere about us. What we need
Is the celestial fire to change the flint
Into transparent crystal, bright and clear.*

— LONGFELLOW

17. Matter, Organic and Inorganic. — The apple tree and codling moth both carry on life functions by means of certain *organs*. For this reason they and all other living things are called *organisms*, and are said to be composed of *organic* matter.

We cannot say this about water, rocks, soil, air, or iron. These substances are all non-living and are called *inorganic*. Wood, sugar, meat, oil, and coal are likewise dead, but each was once part of some living organism; therefore, they too are called *organic*. Organic substances, then, are substances that are living, have lived, or are produced by living things (milk, eggs, etc.). How many other kinds of organic matter can you name?

Both plants and animals take into their bodies inorganic matter and make it a part of themselves. These inorganic materials are then in the living substance and as long as they remain there, they are properly described as organic. The story of the apple tree and the codling moth revealed that all of the material in the bodies of these two organisms was eventually returned to the soil and air.

18. Elements and Compounds. — All matter, whether organic or inorganic, is composed of elements and compounds. An *element* is a substance which has not been separated into other substances by chemical action. Iron, carbon, oxygen, copper, and gold are elements.

A *compound* is a chemical combination of two or more elements in which each loses its identity or distinctive properties. Water,

sugar, olive oil, the white of an egg are compounds because each contains two or more elements united according to the laws governing chemical combinations. The starch found in wheat, potatoes, and corn is a compound of three elements, namely, hydrogen, carbon, and oxygen. Water is a compound made up of hydrogen and oxygen. Compounds are more numerous in nature

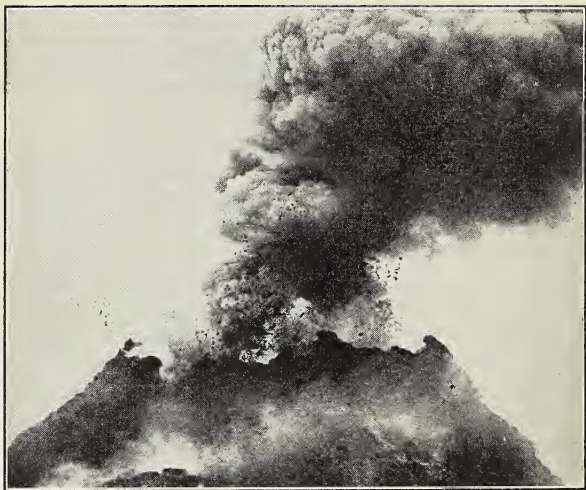


FIGURE 20. AN ERUPTING VOLCANO

How many forms of matter are shown here?

than elements. In fact, there are many thousands of compounds, while there are but ninety-two elements.

A *mixture* is a physical blending of materials, in which each keeps its own nature and properties, as in lemonade. A mixture differs from a compound in that it is not formed by chemical action, and the elements of which it is composed do not lose their special properties.

19. Gases, Liquids, and Solids. — The elements and compounds which have just been discussed exist either as a gas, a

liquid, or a solid. Each of these terms has a technical meaning, but for our purposes in understanding life processes, the following simple definitions are sufficient.

A *gas* has neither definite size nor shape. There are no limits to the amount of expansion that may take place in it. The minute particles of which it is composed can move in any direction. If gas is confined in a glass bottle, the limits of its expansion will be the sides of the bottle. Air, steam, and hydrogen are gases.

A *liquid* has definite quantity, but takes the shape of the vessel containing it. The particles of which it is composed move over one another without any apparent resistance. It is not capable of indefinite expansion, and if placed in a bottle, it would not necessarily fill the entire bottle as would a gas. Water, milk, and oil are liquids.

A *solid* has definite quantity and shape and offers resistance to any change. In solids the particles are so firmly united that they are not easily separated. Sugar, wood, and rock are illustrations of solids.

20. Physical and Chemical Change. — If a solid piece of ice is melted, it becomes liquid water. If the liquid water is boiled, it becomes steam, a gas. If the steam is cooled, it becomes water, which in turn may again be frozen into ice. Any change in a substance which does not alter the material of which it is composed is called a *physical change*.

On the other hand, when oxygen unites with wood, the wood burns, giving off heat and smoke, and ash remains. But this ash cannot be united with heat and smoke to form the original wood. Such a change as is seen in the burning of wood — that is, one involving the composition of a substance — is a *chemical change*.

21. Elements in Organisms. — Twenty-nine elements have been found in organisms, but only fourteen are at all common and essential to life. They are ox'ygen, car'bon, hy'drogen, ni'trogen, cal'cium, i'odine, phos'phorus, sul'fur, potas'sium, magne'sium, i'ron, so'dium, chlo'rine, and sil'icon. It is interesting to note that these same elements are also the most numer-

ous in lifeless things such as rocks, water, the atmosphere, and other inorganic matter.

Oxygen is a gas which makes up about one fifth of the air. It is the element which sustains life in animals and plants. Without it they cannot live. When given an undue amount of it, they

develop at an abnormal rate. It forms about seventy per cent of the bodies of plants and animals.

The most striking property of oxygen is the ease with which it unites with other substances; this is *oxidation*. Practically all cases of burning are caused by oxygen uniting with paper, wood, coal, or some other material. If a piece of glowing charcoal is placed in a jar of oxygen, it bursts into flame. This is the test for the presence of oxygen.

Carbon is one of the most important elements in biology. It combines with hydrogen and oxygen to form sugar, starch, fat, and wood. It is usually black and solid and is best seen as the



FIGURE 21. ADJUSTING ALTITUDE EQUIPMENT

This apparatus enables flyers to breathe even at very high altitudes. It was used on the first flight over Mt. Everest.

charred remains of certain foods that have been overheated but not burned up, as when toast or meat is "burned." Carbon forms about fourteen per cent of the bodies of plants and animals.

Hydrogen gas is the lightest of all substances. It is found in nature combined with other elements; it enters into the composition of water, animals, and plants. It forms a little less than

ten per cent of the weight of bodies of organisms. It is an odorless, colorless, and tasteless gas, very combustible.

Nitrogen is a gas which does not burn. It dilutes the oxygen of the air in the proportion of four to one, and so makes it less active. Nitrogen forms less than three per cent of the bodies of plants and animals.

Calcium, sulfur, phosphorus, iron, iodine, potassium, chlorine, silicon, magnesium, and sodium are the other important elements found in living things. All of these elements occur in very small amounts.

22. Nutrients. — The elements above, while composing the body structure in intricate compounds, are not taken directly as food. The foods we commonly use have these elements in combination with other materials. The foods that contain the proper elements and compounds are spoken of as *nutrients* or food compounds. These nutrients are carbohydrates (starches and sugars), edible fats, proteins, and mineral matter.

Starch. — Starch is a very essential nutrient that occurs in many of our foods. Potatoes, corn, wheat, rye, rice, and most of the vegetable foods contain large amounts of starch. Starch is always changed to glucose by the digestive fluids. It furnishes most of the energy for the heat and motion of the body.

Grape Sugar. — Grape sugar is a nutrient that occurs in grapes and in most other fruits. It is slightly different in composition from cane sugar and beet sugar. Starch is always changed into grape sugar or glucose by the digestive fluids and never into cane sugar. The food value of both glucose and cane sugar is high. They are used by the body to furnish the energy of heat and motion.

Edible Fats. — The term *edible fats* is used to include both fats and oil. These nutrients are almost wholly energy producers. They are used chiefly to produce heat. As we go north or south from the equator, we find the native people adding ever greater amounts of fats to their diet, until we come to the Eskimos, who eat large quantities of pure fat with relish. Large amounts of fat are necessary to keep the body warm in the very cold zones.

Starch, sugars, and fats are all composed of carbon, oxygen, and hydrogen.

Proteins. — Proteins are nutrients that are found in great variety in our food. The proteins differ from starch, sugar, and oils in having nitrogen in combination with other elements. The characteristic element of protein is nitrogen. Each kind of protein has its own name. The protein in wheat is *gluten*; in beans it is *legumin*. *Casein* is the protein in milk and *myosin* is the protein in meat. The proteins are necessary in building



FIGURE 22. AN ESKIMO FAMILY

Ewing Galloway

What kind of food do you think they are eating?

and repairing the cells of animal bodies. If more proteins are eaten than are necessary for this work, the surplus may be oxidized to furnish the energy of heat and motion or stored as fat.

Mineral Foods. — In addition to the nutrients already mentioned, which were starch, sugars, edible fats, and proteins, there are many minerals that are necessary for the proper development and growth of animals and plants. These mineral foods contain iron, sodium, potassium (potash), iodine, calcium, sulfur, and phosphorus.

Iron is necessary as a part of the red blood cells to enable them to carry oxygen from the lungs to all parts of the body. Sodium

is needed to help the cells of the body perform their work properly. Potassium (or potash as it is commonly called) is particularly necessary for the growth of plant cells and to a less extent for animal cells. Iodine is needed especially by the important thyroid gland. Calcium gives hardness to the bones of animal skeletons, including teeth and the shells of clams and oysters. Phosphorus contributes to the growth of cells of animals and is an important plant food.

Many foods that have but little starch, sugar, or protein are valuable because of the mineral salts they contain. For example, prunes contain iron, sodium, potassium, and phosphorus. Spinach has iron and sodium. Carrots have sodium and calcium. Oysters and other sea foods contain iodine. Peanuts have phosphorus and calcium. The foods just mentioned, along with many others, are necessary foods because of their mineral content and also because they are rich in what we call *vitamins*.

23. Body Regulators. — Water, an inorganic liquid, is not a food in the sense that it is broken up and digested as real foods are. Because of its power to dissolve foods, it is called a *universal solvent*, and all foods are put into the form of solutions by the use of water. Blood is water in which are floating red and white cells and a great variety of foods and wastes. The tissues of animals and plants are soft in large part because of their water content. Our bodies are over seventy per cent water; there is some water even in bones. Water is necessary in the distribution of foods in all living things and in the removal of wastes. The habits of wild animals which frequently travel long distances for water, and the severity of human suffering when water gives out, as it sometimes does in the crossing of a desert, indicate how necessary water is in the daily life of the higher animals. Animals die when the water in their tissues is frozen or when it is withdrawn in extreme evaporation.

Water is so familiar to us all that no special tests are necessary to identify it. It is made up of two gases, oxygen and hydrogen, which are united in the proportion of two parts of hydrogen to

one of oxygen. It is a product of the burning of fuels which contain hydrogen.

Vitamins. — The terms *proteins, starch, sugars, fats, mineral food, and water* do not completely enumerate all of the substances that are necessary in a satisfactory diet for living things. There has recently been discovered a series of substances which are known as vitamins. As to just what these substances are we are still in doubt, but they can be proved to be present in some of our



Courtesy Northern Pacific Railway

FIGURE 23. REFRESHING THEMSELVES AT A SMALL CREEK

Water is necessary to all animals.

ordinary foods like milk, tomatoes, fruit, and lettuce. They will be discussed more in detail in § 361.

24. Waste Products. — *Carbon Dioxide.* — When a fuel is burned, the oxygen of the air unites with the carbon of the fuel. When this union is complete — when the carbon combines with the largest possible amount of oxygen — the gas, carbon dioxide, is formed. (This gas is also called *carbonic acid gas*; you know it as the bubbles of soda water.) Similarly, when fuel (food) is burned in the bodies of organisms, one of the waste products is carbon dioxide. This gas, like water, is described as inorganic.

Organic Ash. — When coal is burned in the furnace, or wood in the stove, there remains a grayish product known as *ash*. Simi-

larly in the burning of fuel in the body of organisms there are waste products which we might include under the comprehensive term of *organic ash*.

LABORATORY WORK

Demonstration of Important Substances. — *Carbon.* — Burn a piece of paper. What is the black part that is left? Burn a shaving. What is the black part that is left? Light a candle and hold a dish just above the flame. What is the black material on the dish? A diamond is crystallized carbon. Is carbon black when crystallized?

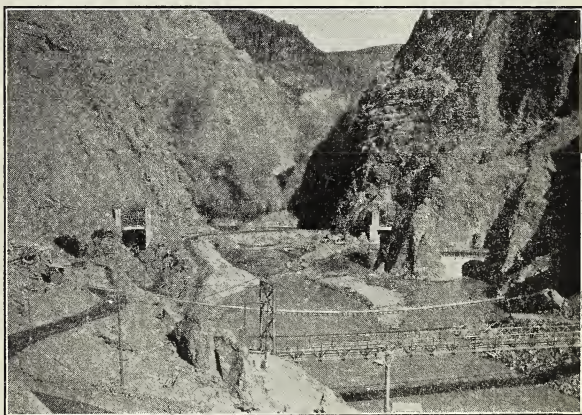
Oxygen. — Heat mercuric oxide in a hard-glass test tube. What is the color of mercuric oxide when you first put it in the test tube? What is its color when heated? After heating the mercuric oxide for a few minutes thrust a glowing splinter of a broom into the open end of the test tube. Does it burst into flame? If it does, oxygen was present. Does oxygen have color? Is oxygen a gas, a liquid, or a solid? What is the effect of oxygen on burning (oxidation)?

Hydrogen. — Put some small pieces of zinc or some tacks into a bottle that takes a large rubber stopper with two holes. Put a funnel through one of the holes and a small piece of glass tubing in the other. Pour water through the funnel until the lower end of the funnel is under water. Connect a rubber tube to the end of the glass tube. Pour hydrochloric acid through the funnel. Do the acid and water bubble? Do the bubbles come from the zinc? Over the end of the rubber tubing hold an empty test tube with the open end down. With the open end still down bring it near a flame. What happens? Could you hear anything? If you heard a barking sound and saw a flash, you had a mixture of hydrogen and air and it exploded with the aid of the flame. Is hydrogen a gas? Does it have color? Why should the open end of the test tube be held downward while the gas is collected? Which is heavier, hydrogen or air?

Nitrogen. — Cut a thin slice from a large candle and float it in a pan partly full of water. If it floats readily, light it and invert a large jar over it. What happens to the water? Does it rise or fall? After the candle goes out, does the water rise or fall? Why? If the water rose one fifth of the distance to the top of the jar, what would you say had happened to the oxygen in the jar? If the oxygen has been taken from the jar by the burning flame, what is left? What part of the air is oxygen? nitrogen? carbon dioxide? other gases?

Carbon Dioxide. — In the above experiment the carbon in the candle united with the oxygen of the air. As a result carbon dioxide was made. To make it more rapidly we can pour sulfuric acid or other acid (even vinegar) on baking soda. Use the same kind of apparatus that was used in making

hydrogen. Put soda in the bottle, add water, then add acid. Light a candle and place it in the bottom of a beaker or bowl. Let the rubber tubing reach to the bottom of the beaker. What happens to the flame? What will carbon dioxide do to a flame? What are fire extinguishers? Do any of them depend on the manufacture of carbon dioxide when they are inverted? Bubble some of the carbon dioxide through lime water placed in a test tube. What happens to the lime water? What is the color change? Slowly breathe through a small glass tube into a test tube half-full of lime water. What happens to the lime water? What is the cause of this? What is the source of the carbon dioxide that animals breathe out? What use do plants make of carbon dioxide?



Courtesy Bureau of Reclamation

FIGURE 24. BLASTING ROCK IN THE CONSTRUCTION OF A DAM

How is kinetic energy used here to create potential energy?

25. Kinds of Energy. — Heat results from the burning of a substance by fire or from the burning of fuel in the body of organisms. In this burning energy is set free. The heat from a burning candle is due to a rapid movement in the burning particles of the candle. The heat in organisms is due to a similar movement in the particles of protoplasm. All of the material of our physical universe is in constant motion. These movements may be large enough to be seen or so small that we recognize them only as heat.

Energy is defined as the power to do work. There are two kinds of energy: active or *kinetic*, and stored or *potential* energy. *Kinetic* energy is the energy which a body is using on account of its being in motion. Kinetic energy may be used in starting matter in motion, or in raising its temperature, or in altering the position of a body, or in producing chemical changes.

Potential energy is inactive energy such as that of the water stored or restrained by a dam, and the fuel properties in wood. The stretched watch spring in a watch has potential energy. An object cannot have potential energy except as the result of the previous expenditure of energy upon it.

26. Important Forms of Energy. — The movements in animals and plants, the heat utilized by them, the growing of new parts, in short, all of the life processes depend upon energy. Not only must living things procure and use energy to sustain life, but they are influenced by such forms of energy as heat, light, electricity, mechanical or physical energy, and gravity, which acts upon the entire organism from without.

Heat. — Heat is an important factor in the life of organisms because in nearly all instances their life functions are possible only within rather narrow ranges of temperature. In general, life is possible only between freezing and boiling temperatures. Some living things can be temporarily frozen, for example, the frog and certain fish, and later be revived; while a few of the lower plants live in the hot springs in Yellowstone National Park. But for most organisms these extremes are fatal. The effect of heat on life may readily be seen in the case of hens' eggs. In cold storage they will keep for months, but at the proper temperature they hatch into chicks in a few weeks.

Light. — Light is indispensable for the growth of most plants, though not all parts of the plant respond to light. As a general rule the stem turns toward the light and the roots away from it, while the leaf turns so as to expose its broad surface to the direct rays of light. Sunlight and especially its ultra-violet rays are necessary for the growth of animals. It is important to remember, however, that many animals are active only in the absence of

light, or, as we commonly say, at night. It is hard to separate entirely the influence of light from that of heat because the two are constantly present, to a greater or lesser degree.

A striking illustration of the effect of light on the growth of living things is found in our dense forests. Spruces surrounded by large trees, thirty to fifty feet high, which shut off most of



Courtesy Northern Pacific Railway

FIGURE 25. JUPITER TERRACE, YELLOWSTONE PARK

Even in these hot springs some plants survive.

the direct sunlight, have been found to grow only six or eight feet in fifty or sixty years.

Motion. — The influence of motion or mechanical energy on the life of organisms is easily seen by those who are able to study the life in a rapidly flowing brook or to observe isolated trees growing on a wind-swept hill. If the winds are largely in one direction, such trees will have the size and number of their limbs reduced on the side from which the prevailing wind comes and will have much longer and more numerous limbs on the opposite side. The normal growth of plants can be greatly altered if they are

placed upon moving platforms. The extent of the alterations will depend on the rate at which they are moved.

Gravity. — Gravity is the attraction of the earth for all bodies. It is a form of energy that acts all the time and does not vary in amount. In this respect it differs from temperature, light, and motion. Stems tend to grow away from the center of the earth and roots to grow toward the center of the earth.

27. Conservation of

Energy. — When a man winds his watch, he transforms the kinetic energy of his hand into the potential energy of the watch spring; and this potential energy in the watch spring in turn passes into kinetic energy

in moving the hands of the watch. Thus energy is passed on and conserved. Let us see if we can apply this same idea to living things.

The light of the sun enables plants to grow and store up food in the form of sugar and starches. Ages ago there was a very luxuriant growth of plants in certain districts where coal is now found. These plants shed their numerous leaves, which were gradually changed into peat, and later covered by sand and clay and subjected to great pressure and heat. Under these conditions this organic plant material was transformed into *coal*. The uses to which this potential energy in the coal can be put serve as an illustration of the conservation of energy.

The light of the sun made plants grow which were later transformed into coal. The coal is burned under the boiler, making the steam which runs the engine. The engine turns a dynamo and produces electricity. The electricity is passed through a small wire in an electric bulb and furnishes light. Thus the light of



FIGURE 26. AN EXPOSED TREE
How has the wind affected this tree?

ages ago is again made into light by this long process. It has traveled in a circle, so to speak.

Energy may be converted into various forms. Electricity may be changed to heat, as in the electric flatiron; into light, as in the electric bulb; or into motion, as in the trolley car. If energy is used in one form, it will appear in some other form.

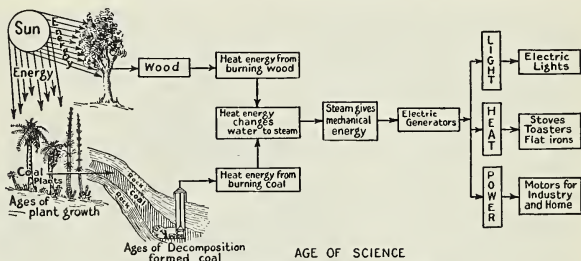


FIGURE 27. TRANSFORMATION OF ENERGY

This diagram shows several ways in which energy is converted.

Energy cannot be created or destroyed. This is the law of the conservation of energy.

28. Conservation of Matter. — There is a similar law in regard to matter. That, too, cannot be destroyed. When a paper burns, it disappears as paper, but the matter of which it consisted still exists in the form of the ash which is left and the gases which passed off during the burning.

SUMMARY

In this chapter we have seen how all matter, whether organic or inorganic, is made up of certain elements. There are over ninety elements, including the four which are important in biology: oxygen, carbon, hydrogen, and nitrogen. These four make up a large part of the human body. Elements and compounds may be gases, liquids, or solids.

Food is required to maintain these elements in the body. The nutrients contained in food are starch, sugars, edible fats, proteins, and mineral matter. Besides these there are certain body regulators that are not classed as nutrients. These are water, vitamins, and the substances which make up organic ash.

These nutrients must go through certain physical and chemical changes to produce energy in the body. Active energy is called *kinetic*, stored or latent energy is called *potential*. There are many forms of energy, such as heat, light, motion, and the pull of gravity, but energy can be neither created nor destroyed. And the same is true of matter.

QUESTIONS

What is the difference between organic and inorganic matter? Illustrate each. What is an element? Name several important ones. What is the difference between a compound and a mixture? In what forms is matter found? Is air a gas? Is steam? What is the difference between physical and chemical change? What four elements make up the bulk of the human body? Name the chief nutrients. How is starch changed into grape sugar? What is the chief function of proteins? of fats? How does water help the nutritive processes? What is the value of mineral foods? Name some foods containing vitamins.

What is energy? What is the difference between kinetic and potential energy? Is life dependent upon energy? Why? Name four important forms of energy. How does each one influence life? Explain the conservation of energy; of matter.

REFERENCES

Cockerell, *Zoölogy*, Chapter I, World Book Company

Snyder, *Chemistry of Plants and Animals*, Chapters I-IX, The Macmillan Company

CHAPTER IV

THE GREEN PLANT AS A FOOD FACTORY

Man is dependent upon plants, which alone are able to manufacture food from the inorganic world. — ATWELL

29. The Green Plant. — In the story of the apple tree, we have outlined the meaning of the science of biology (Chapter I), have passed to a study of the life functions in the apple tree and other living things (Chapter II), and followed this by an analysis of the composition of living things (Chapter III). But all life is dependent on food, and all food comes originally from plants like the apple tree that contain green pigment, usually in their leaves. So we will now take up the study of the manufacture of food.

Plants and animals require food for warmth, growth, movement, and the other life functions. Living things are continually using up the kinetic energy which they get from foods or nutrients. If life is to continue, there must be somewhere in nature a place where food is manufactured. This place is the green plant.

To illustrate this any green plant is satisfactory. The leaves of the apple tree which we studied in the first chapter will do. This process or function of manufacturing food is not present in animals or in the colorless plants. It is different from all the life functions defined in § 15 and must not be confused with any of them.

30. Photosynthesis. — The primary activity of the green apple tree leaves is to *manufacture food*. In order to distinguish this process from all other life functions a special term is applied to it, that is, *photosynthesis*. This word is from the Greek, *phos*, light, and *synthesis*, composition, and means putting together through the influence of light. The raw materials which are used in this activity are water and carbon dioxide, which are the waste prod-

ucts of most oxidation (§§ 21, 24, 31). The energy required to unite these two compounds is derived from the sun.

The water enters the roots of the apple tree, passes up the stem, into the branches, and finally into the leaves. No water is obtained directly from the atmosphere. Only a relatively small portion of the water actually taken up by the roots is used in food manufacture, as the greater part passes off from the leaves.

The carbon dioxide used is derived almost entirely from the air, where it is always present. The supply in the atmosphere is constantly being augmented as the result of oxidation in animals and plants, as well as in the non-living world, for example, in the breaking down of limestone.

The means by which these materials are combined is a green pigment, called *chlorophyll*, which is located in a special body or structure called the *chloroplast*. In the leaves of the apple tree these tiny green bodies (Figure 28) are numerous and round in shape.

One of the first foods to be manufactured by the leaf is the carbohydrate, grape sugar, which is the basis on which the plant builds the remaining food nutrients. In the manufacture of sugar the oxygen which is not needed is released and given off to be used by either animals or plants in respiration.

It requires energy to combine water and carbon dioxide into sugar. Before this new combination can be made each of these substances must be broken up, for in the new combination not all of the oxygen is needed. The energy for this process is derived entirely from light.

The importance of photosynthesis can hardly be overestimated. Through this special life process in green plants, potential energy

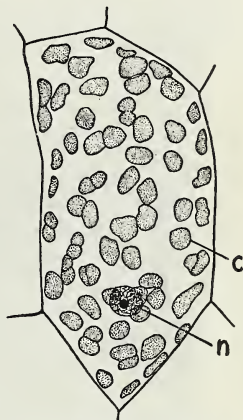


FIGURE 28. PLANT CELLS WITH CHLOROPLASTS

Compare their size (*c*) with that of the nucleus (*n*).

is again made available in food. The green plant uses in its life processes some of the food which it has manufactured. This is the reason why the term *food-taking* does not apply to the green plant. The green plant manufactures a great deal more food than it needs for its own life processes, and this excess, often in the form of starch, is stored in various parts of the plant.

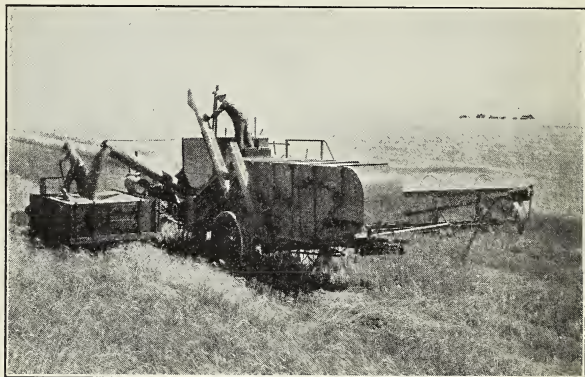


FIGURE 29. COMBINATION THRESHER AND REAPER

Here the wheat is harvested and the wheat kernels which you see pouring out of the pipe at the left of the picture will be sent to a mill to be made into flour.

The insects feeding on the leaf, the stem, the root, and the fruit of the apple tree were absorbing some of this extra energy which the apple tree had manufactured and stored in these various parts. Man and other animals eat the apple, which could not have grown without the food-factories in the leaves.

LABORATORY WORK

Demonstration of Photosynthesis. — To show that light is necessary for photosynthesis, fasten thin discs of cork to the upper and under sides of a leaf with clips, completely shutting off the light. Stand the plant in the bright light for half a day, then remove the corks from the leaf and the leaf from the plant.

Heat enough 60% alcohol to cover the leaf in a shallow glass dish. This may be done by setting the dish in hot water. Keep hot for half an hour, or until the chlorophyll is removed from the leaf. Pour off the alcohol and put drops of weak iodine on the leaf. Note that the circle covered by the cork discs shows little starch or none, as indicated by the faint blue color or by lack of color.

Make a similar test by comparing a leaf from a plant that has been in the dark twelve hours with one that has stood in the bright light for the same time, using alcohol to remove the chlorophyll and iodine as a test for the presence of starch as before.

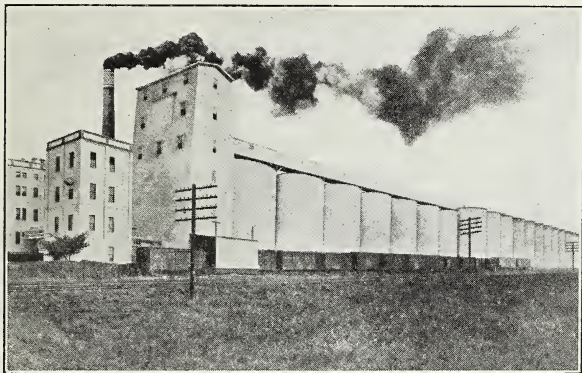


FIGURE 30. A SECTION OF A LARGE FLOUR MILL

Here wheat is made into flour which may be shipped direct to all parts of the world.

31. Oxidation. — Oxidation is the uniting of oxygen with any substance. We are all familiar with oxidation by burning, as in the burning of a match or paper, where it is accompanied by flame, smoke, and heat.

Physiological oxidation takes place in all active organisms. It is a slow process without flame or smoke, but there is always heat, although this may not be apparent. Carbon dioxide and water are set free in this process much as they are when coal burns in a furnace.

We burn coal to keep us warm, prepare our food, and run our machinery. We light a candle or an electric lamp to give us

light. In all such cases the object is secured through the release of *energy*. When this energy has been released, we speak of it as heat or light. Oxidation in organisms is similar. In animals it is the source of heat and muscular power.

An organism cannot carry on its life processes without using energy, but some very simple forms of life use almost no energy for months or even years. Thus seeds of some plants can be kept alive for thirty years, but the statement that seeds may live for hundreds of years is not true. These forms of life that temporarily cease carrying on their life functions are much like a clock that is wound up but not running. The potential energy is there and is only waiting for the necessary forces or conditions to release it.

LABORATORY WORK

Demonstration of Oxidation. — Mix equal parts of potassium chlorate and manganese dioxide and fill a test tube half full. Hold the test tube over an alcohol or gas flame by means of a test-tube holder. As soon as gas seems to be coming off from the mixture, insert a glowing match into the end of the test tube. Notice what happens.

Take a piece of picture wire and, after heating it, dip it in powder of sulfur. Heat it again until it burns and then place the burning end in the test tube containing the heated mixture. What happens?

Each of these operations illustrates oxidation in a striking manner.

32. Digestion. — The food stored in the leaf, the stem, and the root of the apple tree has to be digested before it can be utilized by the apple tree. The food which the codling moth larva secured by eating part of the apple would never have been of advantage unless it had been digested.

Digestion is the process of converting an *insoluble* food into a *soluble* form. The common nutrients all need to be made soluble before their energy can be used in a living organism. These changes are brought about by certain substances called *enzymes* or *ferments*. In plants they are produced by the living cells and in higher animals by the digestive glands. Their importance may be better understood from the illustration in the following paragraph.

Starch is a common food that requires digestion. It is easily changed to glucose (grape sugar) by the digestive fluids. Glucose is an easily absorbed nutrient of high food value that occurs in grapes and in most other fruits. One of the enzymes that change starch to glucose is called *diastase*. There are many other enzymes; *pepsin* is the one in the stomach that digests protein. An enzyme is not changed by digestion, so a very small amount of it digests a large amount of food.

LABORATORY WORK

Demonstration of Digestion. — Artificial pancreatic juice is made by mixing 10 grains (1 gram) of commercial pancreatin and 20 grains (2 grams) of baking soda in 200 cubic centimeters of water.

Take 10 cubic centimeters of the artificial pancreatic juice in a test tube and to it add corn-starch paste. Set for two hours in a place where body temperature can be maintained. Test for grape sugar. This is done as follows: Add to the fluid in the test tube twice as much of Fehling's solution.¹ Gently heat the test tube until the contents turn first yellow and then brick-red. Grape sugar is the only substance that gives this color reaction.

Apply Fehling's solution to some corn-starch paste. Do you get the same color reactions? The changes which the artificial pancreatic juice caused are the same as those that take place in digestion. There are other digestive juices each of which acts on a definite kind of food. These changes are presented in detail in later sections.

33. Osmosis. — All foods and gases that man, animals, and plants require enter the cells in the form of solutions. Foods of the higher animals are dissolved in the stomach and intestine so that they can pass through the lining membrane and eventually into the blood. In plants, absorption of water with dissolved minerals and gases takes place in the root hairs. In both cases

¹ Fehling's solution is made by taking

(1) Copper sulfate	34.5 grams
Water	500 cc.

Set aside until it completely dissolves. This is solution number 1.

(2) Rochelle salts	173 grams
Caustic soda	50 grams
Water	500 cc.

This is solution number 2.

Do not mix until ready to use, then take equal parts of both.

the process is the same. There is a transfer or movement of substances through the cell walls, and this process is called *osmosis*.

Osmosis is the passage of solids and gases in solution through a membrane.

LABORATORY WORK

Demonstration of Osmosis. — Carefully break the shell on the large end of an egg and remove the pieces without breaking the membrane beneath.

Make a hole with a large needle through the shell and membrane of the small end of the egg. With sealing wax fasten a small glass tube (open at each end) over the hole in the smaller end of the egg so that it will not leak. Set the egg with the attached tube in a tumbler half full of water. Put the apparatus away and observe it from time to time for a day or two. Does the egg rise in the tube? How far? Does the egg mix with the water in the tumbler? How much? Test the water in the glass for protein (see § 223).

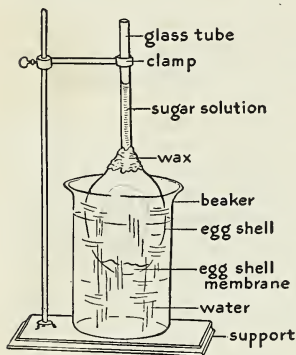


FIGURE 31. OSMOSIS ILLUSTRATED

The water in the glass passes through the egg membrane and forces some of the egg white up in the glass tube.

These food products, largely carbohydrates, are digested by means of enzymes. They are absorbed by the process of osmosis, and become a part of protoplasm; then they are oxidized or burned in the body.

SUMMARY

All life depends on food, and all food comes originally from the green plant. In fact the chief function of the green plant is to manufacture food, which it does by a process known as *photosynthesis*.

QUESTIONS

Why is the green plant so important to us? What is photosynthesis? Describe the process in detail. How is carbon dioxide formed? Of what are the food products called *carbohydrates* composed? What is oxidation? What is a common example of oxidation with which everybody is familiar? How is food digested? Describe osmosis.

REFERENCES

- Gager, *Fundamentals of Botany*, page 33, Blakiston's Son and Company
Sinnott, *Botany, Principles and Problems*, page 69, McGraw Hill Publishing Company
Stiles, *Human Physiology*, Chapter XI, W. B. Saunders Company
Transeau, *General Botany*, Chapter V, World Book Company

CHAPTER V

THE PHYSICAL BASIS OF LIFE

*For men to tell how human life began
Is hard; for who himself beginning knew?*

— MILTON

34. The Cell. — We have studied the principal life functions and the composition of living things. We have referred to cells and we are now to take up a careful study of the *cell*, the unit of both structure and function in all living things.

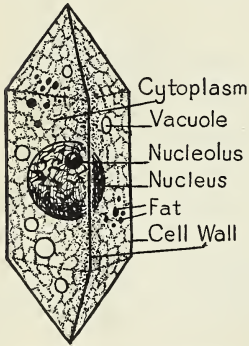


FIGURE 32. A CUCUMBER CELL

Different kinds of cells have different shapes; the shape of a particular kind depends somewhat on the relation of the cell to other cells. This is one of several shapes that a cucumber cell may have.

If we should examine a tiny bit of animal flesh or plant fiber under a microscope, we should see that it is made up of many extremely small units. These tiny units are called *cells*. Each one is made up of a jelly-like substance surrounded by a *cell wall* which incloses a mass of *cytoplasm*. This in turn contains a sac-like body, the *nucleus* (nū'klē-ŭs). The nucleus usually has one or more separate bodies called *nucleoli* (nū-klē'ō-lī). A *cell* is defined, therefore, as a *mass of protoplasm*; its parts are (1) cell wall, (2) cytoplasm, and (3) nucleus (Figure 32). Cells are so small that there are probably several hundred millions in every human body.

The Englishman, Robert Hooke, in 1665 gave the name *cell* to the minute cavities of cork. What he saw was really the dead

cell wall, and it was nearly a hundred years later that the living material in a cell was recognized and described as protoplasm.

LABORATORY WORK

Demonstration of a Cell. — Scrape the inside of your cheek with your finger and place the material collected on a glass slide. Examine it with a compound microscope. Do you find flat cells that are irregular in outline? Examine drawings and see if any of the cells you find are shaped like those in the drawings. What is the shape of the epithelial cells?

Peel off the thin outside layers of plant stems, like onion, Wandering Jew, or lily. Place them in water on a glass slide and examine them with a compound microscope. Do you find flat, thin cells that are similar to the cells from your tongue? Examine charts for details.

35. Cells Divide. — The young apple tree increased in size by making more cells, the "worm in the apple" did the same, and both became larger by adding more cells. Each new cell in the

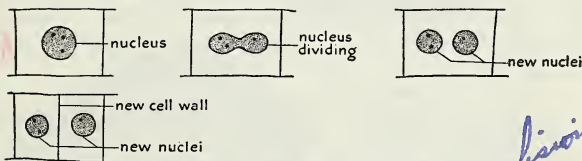


FIGURE 33. DIRECT CELL DIVISION

This type of cell division may occur in both plants and animals but is not common. What seems to be the important difference in this form of cell division and the one pictured in Figure 34?

young apple tree or larval insect is formed from another living cell and the process is known as cell division. It takes place in two ways: first, by a simple or direct cell division (Figure 33) in which the cell is pinched into two cells giving to each half part of the nucleus and part of the cytoplasm; secondly, by the indirect process of cell division which is a more complicated process. The diagrams in Figure 34 show you some of the more important steps and the order in which they occur. This is the usual method of cell division in most animals and plants, and it is important to notice that there is a definite distribution of nuclear material

to the new cells. The new cells in the apple tree and in the larval insect are formed by the indirect method of cell division.

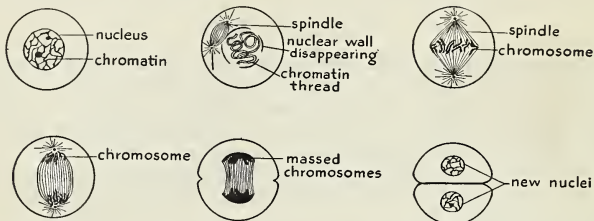


FIGURE 34. INDIRECT CELL DIVISION

This method takes place in plants and animals and is the predominating form of cell division.

36. Tissues and Organs. — After cells divide they take many shapes and sizes, and in all but microscopic plants and animals they are united into tissues which enable the plant or animal to carry on its life processes. A *tissue* is usually defined as *a group of similar cells that do a similar work* (Figure 35).

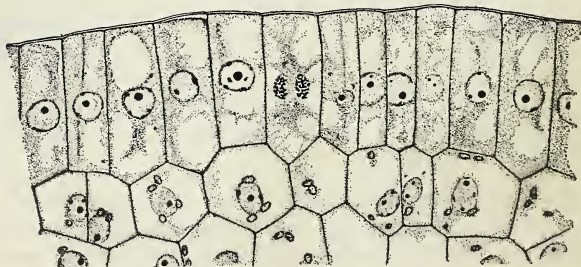
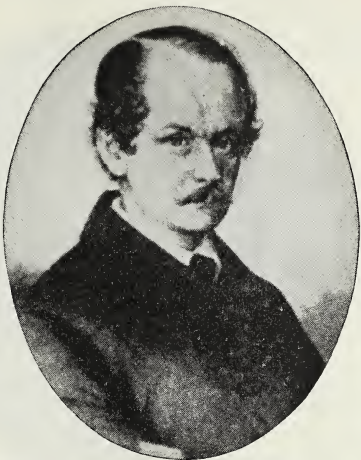


FIGURE 35. OUTER LAYER OF A CUCUMBER PLANT

Professor F. T. Lewis has made a special study of the exact shape of cells and this is his drawing of the outer layer in the cucumber plant. The outer row is a tissue. Apply your definition of tissue.

In all the higher animals the tissues themselves are united into skin, arms, stomach, liver, lungs, kidneys, teeth, hair, and so on, or in plants into leaf, branch, stem, root, and flower. Such struc-

SCHLEIDEN and SCHWANN were two friends who worked on the minute structure of plants and animals. In addition to being very industrious, they were able to value correctly the importance of their discovery (in 1838) that the cell is the unit of structure in which living processes take place.



Matthias Jakob Schleiden (1804-1881) was educated to become a lawyer. You will be interested to look up his life and see how he became a famous scientist.



Theodor Schwann (1810-1882) was trained under the famous teacher of physiology, Johannes Muller, and possessed a personality that was in striking contrast with Schleiden's.



MARCELLO MALPIGHI (1628-1694) gave to Italian scientific men a challenge of excellence that it has been difficult to surpass. This modest, quiet man was born near Bologna of peasant parents. He became a doctor of medicine and was immediately made a teacher in the University of Bologna. He was soon promoted to the University of Pisa.

Malpighi was active in research for forty years, during which time he made important discoveries. He actually saw blood flow through capillaries in the lung of the frog. The pigment layer in the skin is known today as the Malpighian layer. But his fame really lies in the marvelous dissections and drawings that he made. His description of the structure of the silkworm is one of the classic monographs and reveals great skill, for at that time hardly any animal had been carefully described.

His anatomy of plants is one of his best works; in it he foreshadowed the cell theory that was announced more than two hundred years later.

tures are called organs. An *organ* then is a *group of tissues that does a given work in the animal or plant*. Organs form the parts of organisms (see § 17).

37. Protoplasm. — *Protoplasm is the living material of which all cells are composed*. Protoplasm does not exist except in cells. One would expect that a substance so universally present in living things would be easy to describe. But it is hard because the living organism has to be killed before it can be studied. Protoplasm may best be described by comparing it with a familiar object such as the white of an egg, but that is not protoplasm.

Protoplasm is a jelly-like substance that is neither a solid nor a liquid. It is usually colorless or slightly yellow. It can be stretched and when released will contract like rubber. In appearance it is often clear, though it may be opaque, and it may have either a fine granular appearance or a foamy structure like soap bubbles.

All of the life functions occur in the protoplasm and for this reason it is called the physical basis of life. It absorbs, digests, and assimilates food, respire, and excretes. It grows, reproduces, and reacts to stimuli. When we analyze it by chemical methods, we find the same chemical elements already described as present in organisms. The amounts of these different elements vary from second to second and the way in which they are combined is extremely complex, making it very difficult to describe the chemical composition accurately. You should think of protoplasm not as a simple compound but rather as a mixture of several compounds that are *organized* to carry on the life processes. There is no chemical compound or mixture of chemical compounds that man has been able to put together that can be made to do just what the organized compounds in protoplasm have been doing ever since life began.

38. The Microscope. — Living organisms were known for a long time before either the cell or protoplasm was discovered. In earlier times there was no instrument by which one could see these minute bodies that each of you now can see by simply looking through the microscope. The identity of the inventor

of the microscope is in dispute. Hooke and Grew of England, Malpighi of Italy, and Swammerdam and Leeuwenhoek of Holland are the names especially associated with early microscopic observations. Leeuwenhoek became an expert lens grinder and made more than four hundred microscopes and magnifying glasses during his lifetime.

No other single invention has contributed so much to our knowledge of the structure of organisms as the perfected microscope.

39. Environment. — As soon as an organism begins to grow, the life functions are certain to appear. These life functions are passed from parent to offspring in the plant and in the animal, including man.

In marked contrast to these definite life processes of protoplasm, there is the varying factor of the surroundings or *environment* in



Courtesy Bausch and Lomb Optical Company

FIGURE 36. ANTHONY VAN LEEUWENHOEK

This Dutch scientist manufactured many microscopes and is also credited with being the first man actually to see bacteria.

which organisms live. A certain environment is necessary for the manifestation and continuance of life. Land animals, like the dog, die when kept under water; fishes cannot survive in the air; plants perish from lack of moisture; nearly every living thing requires moderate heat and light; and all organisms require food.

SUMMARY

The cell is the unit of both structure and function for all living things. This protoplasm is made up of cytoplasm and a nucleus, which contains one or more nucleoli. All the tissues and organs of the body are made up of cells, which are the units upon which the life functions depend.

QUESTIONS

Describe the cell. Of what is it the unit? Of what is it composed? What goes to make up organs and tissues? Are the life processes fixed? Is environment uniform? Illustrate your answer.

REFERENCES

Cockerell, *Zoölogy*, Chapters II, III, IV, World Book Company
Gager, *Fundamentals of Botany*, Chapter II, Blakiston's Son and Company
Sinnott, *Botany, Principles and Problems*, Chapter IX, McGraw Hill Publishing Company
Smallwood, *Man — The Animal*, Chapter III, The Macmillan Company
Transeau, *General Botany*, Chapters III and IV, World Book Company

Test I

I. Copy the following sentences, placing a + before each true statement and a 0 before each false statement. Do not mark your book.

1. The apple tree has more enemies than it has helpers.
- T 2. The fruit of the apple is a device for distributing seeds.
- T 3. The apple tree has the same life functions as animals.
- F 4. Every living thing has many adaptations.
- F 5. A compound is a mixture.
- F 6. Carbon is the most important element.
- F 7. Water is a food.
- F 8. Potential energy is active.
- F 9. Nutrition is a simple process.
10. A compound and a mixture are the same.
11. Oxygen is the lightest gas.
12. Carbon is a gas.
13. Nitrogen is a solid.

II. Copy the following sentences, filling in the blanks. Do not mark your book.

1. All matter is either solid or liquid.
2. There are about 92 elements.
3. There are thousands of compounds.
4. Air is in the form of gas.
5. Water is in the form of liquid.
6. Sugar is in the form of solid.

7. Two forms of protein are albumen and gelatin.
8. The melting of ice is a physical change.
9. The burning of coal is a chemical change.
10. Neither energy nor matter can be destroyed.

III. Answer the following questions on a separate piece of paper, numbering your answers to agree with the numbers of the questions. Do not mark your book.

1. What are the only organisms that are able to make food? Plants
2. Where does photosynthesis take place? Chloroplast
3. What conditions are necessary? Light & CO₂
4. What kinds of food are made? Carbohydrates
5. What gas is formed by oxidation? Oxygen
6. What is the function of enzymes? They speed up chemical reactions
7. How do roots get water from the soil? By osmosis
8. What are the parts of a cell?
9. Of what are organs made up?
10. Who gave biology the word *cell*?
11. When were microscopes first used?
12. What creature has greatest control over its environment? Man

UNIT II: THE BIOLOGY OF ANIMAL LIFE

CHAPTER VI

THE GRASSHOPPER, A TYPICAL INSECT

*Happy insect! what can be
In happiness compared to thee?*

— ABRAHAM COWLEY

40. Insects in General. — Insects are so widely distributed, have such a great variety of form and color, and are so numerous that the age in which man lives is sometimes called the Age of Insects.

Annual Loss by Insects in U.S. \$ 800,000,000

Annual Loss by Fire in U.S. \$ 143,600,000



Natural History

FIGURE 37. THE LOSS CAUSED BY INSECTS

Will man be able to reduce this loss?

The creatures that compete most with man for domination of the earth are not the lions, rattlesnakes, or other large enemies, but the hosts of small animals of which the insects form the largest class. The building of the Panama Canal was as much

a triumph over the disease-carrying mosquito as it was an engineering feat.

We have to pay more for food on account of the large quantities destroyed by insects, and it is in the interest of food conservation that people should learn the common facts about them. To do this we must get an idea of how they grow, how they get their food, what they eat, where their eggs are laid, how they reproduce, and how they may be controlled.



FIGURE 38. YELLOW JACKET AND PART OF NEST

Notice the interesting construction of the nest. Of what is it made?

It is fascinating to watch insects, because they are always busy at something. Some are flying from flower to flower, others are busy on leaves or stems, and a few minutes of observation will show you whether they are friends or foes of the plant on which you find them. The most interesting way to study insects is to watch them in their native places, but when this is impossible, they can easily be studied in the laboratory. Even in the city a surprisingly large number of different insects can be collected.

Insects perform all the life functions just as large animals do. All insects must have food, all must get oxygen, all have some means of self-protection, all reproduce, and all sooner or later die of accident, disease, or old age. Therefore, when we study one insect, its life history and activities, we get a good general idea of how all of them live.

41. The Study of Insects. — One of the first men to study insects in their home life was Jean Henri Fabre, who lived in southern France in the Rhone valley. Here he studied so attentively that his peasant neighbors thought him queer. Little

did they know that what he wrote about his studies would be read all over the world. Fabre wrote more of the behavior of insects than of their structure. Here is a quotation from what he wrote of the mining bee.

The Mining Bee. — She builds her galleries in firm soil, where there is no danger of landslides. The well-leveled paths in my garden suit her to perfection. Every spring she takes possession of them, never alone, but in gangs whose number varies greatly, amounting sometimes to as many as a hundred. In this way she founds what may be described as a small township.

Each bee has her home, a house which no one but the owner has a right to enter. A good beating would soon call to order any adventuress bee who dared to make her way into another's dwelling. Let each keep to her own place and perfect peace will reign in this new-formed society.

Operations begin in April, very quietly, the only sign of the underground works being the little mounds of fresh earth. The laborers show themselves very seldom, so busy are they at the bottom of their pits. At moments, here and there, the summit of a tiny molehill begins to totter and tumble down the slopes of the cone: it is a worker coming up with her armful of rubbish and shooting it outside, without showing herself in the open.

May arrives, gay with flowers and sunshine. The diggers of April have turned themselves into harvesters. At every moment I see them settling all befloured with yellow, on top of the molehills now turned into craters.

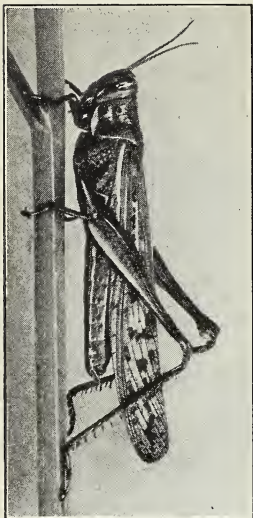
The bee's home underneath consists first of a nearly vertical shaft, which goes down into the ground from eight to twelve inches. This is the entrance hall. It is about as big around as a thick lead-pencil.

At the foot of this shaft is what we might call the basement of the house, the cells. These are oval hollows, three-quarters of an inch long, dug out of clay. They end in a short bottle-neck that widens into a graceful mouth. All of them open into the passage.

42. The Grasshopper. — Let us take as a typical insect the common grasshopper. Large numbers of grasshoppers are to be found in the fields in the summer time flitting and jumping about. Differences in the wings and in the shape and size of the body tell us that there are various kinds of grasshoppers.

43. Life Processes of the Grasshopper. — Many tasks and problems confront the young grasshopper. It must avoid being eaten, must find food, must have oxygen to breathe, must be able to rid its body of waste substances, must be able to see, feel, and

taste, must develop into an adult, and must do its part in providing for another generation of grasshoppers. If the grasshopper fails in any one of the first of these, it cannot live, and consequently cannot perform the last and very important work of providing for the next generation.



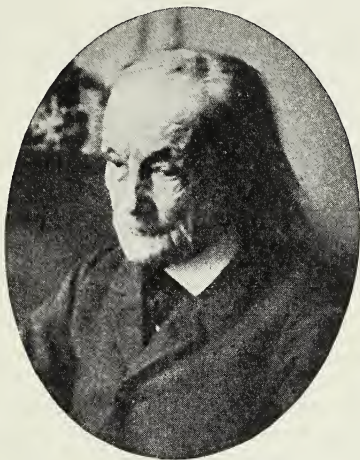
U. S. Bureau of Entomology

FIGURE 39. THE GRASSHOPPER
How is each leg being used?

44. Means of Protection. — The grasshopper, as we shall find, is provided with many adaptations which help it to escape being caught and eaten. The most important of these are its color and markings. When a grasshopper jumps into the grass and remains quiet, its color so closely resembles that of the grass and twigs that many of its enemies overlook it. It is further protected by a pair of large eyes and by simple ears, which are located on the side of the body. These sense organs enable it to know when its enemies are near. The quickness of grasshoppers in jumping also helps them to escape being eaten.

LABORATORY STUDY

Examine a live grasshopper. What are its means of locomotion? Compare its jump with its length. What would be the proportional distance for a man six feet tall to jump? How does the grasshopper obtain food? What protection from enemies does it gain from its color? Notice the division of the body into three regions: *head*, *thorax* (thō'rāks), which has wings and legs, and *abdomen* (ăb-dō'měn). How large is the head compared with the thorax and abdomen? The body is covered with a skin-like substance, known as *chitin* (kī'tin). This is called the skeleton of the grasshopper, and because it is on the outside of the body it is termed an *exoskeleton*. How does it protect the grasshopper? When the living grasshopper is held between the thumb and finger, it "spits molasses." This is partially digested food from its crop.



JEAN HENRI FABRE (1823-1915) was born in southern France. He was a teacher in the *lycée* of Avignon and a professor of physics at the college of Ajaccio. His greatest work was the writing of ten volumes on insects. He also wrote on physics, history, astronomy, and botany. Some of his writings that have been translated into English are *Social Life of Insects*, *The Life of the Spider*, *The Life of the Fly*. He was a careful observer and wrote in a way to interest the reader. He wrote to be understood and sometimes sacrificed accuracy for clarity. His greatest admirers came from the world of literature rather than from the world of science. His writings are still popular and no one has quite filled his place in recent years.

The picture reproduced here was made by one of his sons when Fabre was more than ninety years old.

45. Body Structure. — There are three main body regions in the grasshopper: the head, the thorax, and the abdomen. Each one is adapted to do certain kinds of work. The head structures

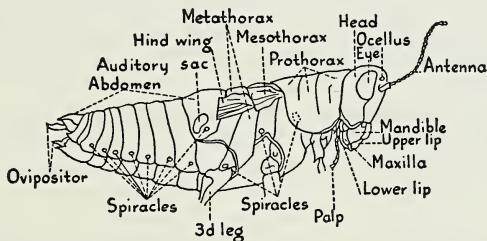


FIGURE 40. THE MAIN REGIONS OF THE GRASSHOPPER — WINGS REMOVED

are adapted to food-getting, seeing, and feeling. The thorax has appendages for locomotion: walking, jumping, and flying. The abdomen is adapted to breathing, hearing, and reproduction.

The Head. — On the front of the head are three simple eyes and on the sides two compound eyes. Near the simple eyes are two antennæ for feeling. The mouth has several special parts for food-getting. (See Figures 40 and 41.) These are an upper lip (labrum) and a lower lip (labium) for moving the food into the mouth. Inside the mouth is a pair of mandibles for cutting and a pair of maxillæ with palps for carrying the food. The hypopharynx, a sort of tongue, is useful in handling the food.

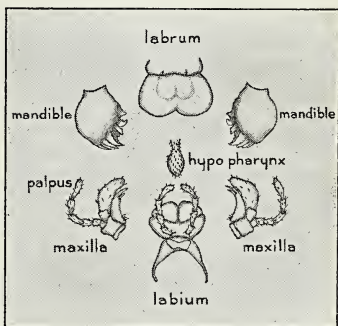


FIGURE 41. THE LIPS AND TEETH OF THE GRASSHOPPER

Examine a grasshopper and discover how each part is used in eating.

The Thorax. — The middle region of the body is called the thorax. It is composed of three parts. The prothorax, separate

from the rest, is provided with the first pair of appendages, in this case legs. The mesothorax, provided with a second pair of legs and the first pair of wings, is not clearly separated from the third part of the thorax, the metathorax. This last section of the thorax supports the most serviceable appendages, a pair of strong jumping legs and the second pair of wings (the flying wings).

The Abdomen. — The third body region or abdomen is clearly divided into ten segments. The first segment, a partial one, contains the two sacs which probably enable the grasshopper to hear, and two small abdominal openings called spiracles (spīr'á-k'lz), one on each side. Fourteen other spiracles are found on the next seven segments, seven spiracles on each side. The last two segments have no spiracles. Instead they are modified for reproduction. The spiracles are used for breathing, and the auditory sac possibly for hearing. In the female the last segment of the abdomen is provided with two pairs of blunt spines that serve as an egg-laying organ called ovipositor.

LABORATORY STUDY

Decide where the divisions of the body of the grasshopper come: head, thorax, and abdomen; the position of eyes. How are the antennæ related to the eyes? How many distinct mouth parts are there? How do the jaws work?

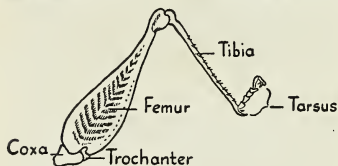


FIGURE 42. JUMPING LEG OF THE GRASSHOPPER

How does this leg differ from the other legs? Explain.

Notice the attachment of the head to the thorax. The head fits into the thorax. The loose anterior (front) portion of the thorax is the prothorax (forward thorax). The first pair of legs is attached to it. Sketch the prothorax to show it and its legs. The portion of the thorax back of the prothorax is divided

into two regions: the mesothorax (middle thorax) and the metathorax (back thorax). The line between them is not clear. Sketch these parts together with the legs and the wings. The jumping legs are attached to the metathorax; the outer wings to the mesothorax; the inner wings to the metathorax. The inner wings are used in flying. The leg of the grasshopper consists of: (1) a small section close to the body (the trochanter); a long muscular part

free from spines (femur); a slender spiny part (tibia); and three segments of the foot (tarsus). The last segment of the foot is furnished with hooks which help the grasshopper in climbing; the spines on the tibia prevent slipping as the grasshopper jumps. The large muscles in the femurs of the last pair of legs, the spines on the tibia, and the hooks on the tarsus are special adaptations which help the grasshopper in various ways.

Notice the tapering abdomen, composed of ten segments or parts of segments. Notice the depression and membrane in the first segment. This is the auditory organ, but it is not a true ear. The spiracles are located on the sides of the abdomen and thorax.

46. Food-Getting.—Food is the least of the grasshopper's troubles. It eats leaves, particularly blades of grass. It does not need a keen sense of smell, as does the bee which must search for flowers. However, the grasshopper has special smelling organs located in its *antennæ* (ăn-těn'ē), those long feelers which grow out from the head like flexible horns.

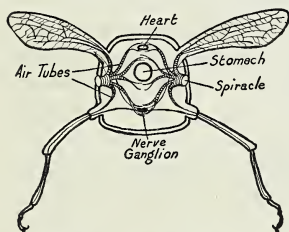


FIGURE 44. CROSS SECTION OF THE THORAX OF THE GRASSHOPPER TO SHOW THE RESPIRATORY ORGANS

do, nor does it breathe through its mouth. On each side of the abdomen are eight evenly arranged spiracles, which lead into branching tubes, *tracheæ* (trā'kē-ē). There are also two spiracles

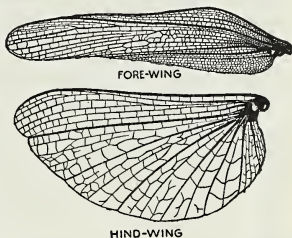


FIGURE 43. WINGS OF THE GRASSHOPPER

How does the grasshopper use each wing in flying? What happens to the hind wing when the grasshopper is not flying?

The chewing parts are so effective that when grasshoppers come in swarms, they strip an area of all its leaves and grass and even destroy whole fields of growing grain.

47. Organs of Respiration.—All animals have some structure which brings oxygen to every portion of their bodies and gets rid of carbon dioxide. The grasshopper does not have lungs as we

on each side of the mesothorax. The branching tracheæ are kept open by means of rings so that the pressure of the muscles and other organs cannot flatten or close them. The tracheæ continue to branch until the subdivisions are so small that they can be seen only by aid of the microscope. These fine branches extend to the minute cells of which the body of the grasshopper is composed. Here the oxygen passes to the living protoplasm of the cells and carbon dioxide is given off to the air which is in these breathing tubes. This use of oxygen by the protoplasm and the giving off of carbon dioxide are *respiration*. (See Respiration, page 17.)

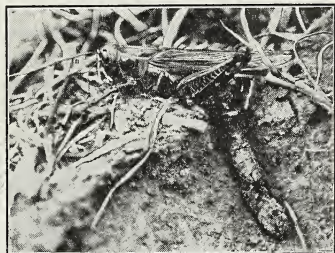
48. Excretion. — The gaseous waste, carbon dioxide, that is formed in all animals as a result of their life processes, in the grasshopper passes from the body into the spiracles and escapes into the air. The liquid wastes are collected by tubes that open into the intestine. The grasshopper must get rid of the waste substances that form in its body or it cannot live. It has organs of excretion which remove all wastes from the body. Besides the waste products of oxidation, there are other wastes which must be eliminated — materials in the grasshopper's food which are so combined that they cannot be digested by the living cells of the insect.

49. Nervous System. — The fundamental life process of irritability (sensation) in the grasshopper is performed by a nervous system. It consists of nerves and ganglia (clusters of nerve cells) arranged in a row beneath the digestive canal and in the head. Nerves connect this central chain of ganglia with all parts of the body. On the head are found compound and simple eyes, special organs for feeling (the antennæ), and organs of taste on the mouth parts. By means of all the specialized nervous organs, the grasshopper is able to see, feel, hear, and taste with a high degree of efficiency and is thus made aware of food and enemies.

50. Method of Reproduction and Life Cycle. — The female lays from 25 to 100 eggs in the autumn in shallow holes which she makes in the ground or in a decayed log. The following spring the eggs hatch into small, wingless grasshoppers called nymphs.

(See Figure 46.) The nymph has a firm outer covering called an exoskeleton, which does not grow so fast as the nymph itself. Accordingly, at certain times, this exoskeleton is shed, and the nymph grows stretching the new one. This shedding or molting continues until the fifth and last molt, when the nymph becomes an adult provided with wings and mature in every sense.

Adult grasshoppers may be found during the summer in meadows, flying, hopping, crawling, and feeding on leaves of grass, grain, and other crops. The adults mate at this time and the females lay eggs to provide for the next generation.



U. S. Department of Agriculture
FIGURE 45. GRASSHOPPER LAYING HER EGGS IN THE GROUND

The earth has been removed to show the grasshopper's abdomen and the pod of eggs. When will they hatch?

51. Metamorphosis. — All animals which pass through different stages of growth in which marked changes in their appearance take place are said to undergo a *metamorphosis* (mēt'-ā-môr'-fō-sīs). These changes are more marked in insects like ants and bees than in the grasshopper. For this reason we speak of two forms of metamorphosis — complete and incomplete.



FIGURE 46. INCOMPLETE METAMORPHOSIS
How long does it take?

Incomplete Metamorphosis. — The newly hatched grasshopper, though very small, looks enough like a wingless grasshopper to be identified as belonging to the grasshopper family. Its form does not change materially from the time it is hatched until it is

full grown. Thus the grasshoppers become adult by a growing process termed *incomplete metamorphosis*, showing no marked change in form (Figure 46).

Complete metamorphosis will be discussed in connection with the butterfly on page 90.

52. Classification of the Grasshopper in Biology. — In order to understand the grasshopper more fully it is necessary to find

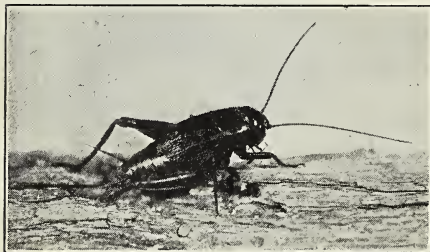


FIGURE 47. A BLACK CRICKET

How does the cricket differ from the grasshopper?

its place in the classification of animals. All known animals have been grouped into a few large divisions for convenience in study. The grasshopper belongs to the large class of animals called *Insecta* (in-sĕk'tā).

The *insects*, as a class, have their bodies divided into three regions — head, thorax, and abdomen. (See Figure 40.) All have three pairs of legs, and most of them two pairs of wings. They take in air by means of air tubes (tracheæ). In becoming adult, all pass through metamorphosis, either complete or incomplete. The insect group is subdivided into fifteen smaller groups or orders.

The grasshopper belongs to the order known as *Orthoptera* (ör-thōp'tēr-ā). In the Orthoptera we find three common families: grasshoppers, crickets, katydids.

53. Economic Importance of the Grasshopper. — Since the grasshopper eats the leaves of plants, a great many of them cause a serious loss of crops. The grasshopper is therefore an enemy of man. The plague of locusts mentioned in the Bible refers to grasshoppers. In some of the western states years ago grasshoppers came in great swarms year after year and destroyed annually crops estimated to be worth \$200,000,000. Parts of China were recently devastated by hordes of grasshoppers. They are

more easily controlled there because the Chinese eat them with relish. Ordinarily, because of the activities of their natural enemies, their number does not become alarming.

Among the natural enemies of these insects are the birds, which do much to control them. Some of the greatest destroyers of grasshoppers are the quail, bluebird, sparrow hawk, butcher bird, crow, red-winged blackbird, and kingbird.



Ewing Galloway

FIGURE 48. A SWARM OF LOCUSTS IN TANGANYIKA, EAST AFRICA

Why are they called the world's worst plague? What parts of the United States were devastated by grasshoppers in 1931 and 1932?

There are closely related insects that are harmful, as the cockroaches, the nuisances of the pantry, and the crickets that eat the roots of plants. There are also tree crickets which frequently lay their eggs in raspberry canes, killing the cane above the place where the egg is laid.

54. What Meaning Has the Grasshopper's Life? — The results of the grasshopper's activities are more important than it might seem. (1) It has eaten plants which might have been useful to cattle or man. (2) It has produced more grasshoppers. (3) It has

served as food for birds and other animals. (4) It has set free waste carbon dioxide which can be used by green plants to assist them in making food. (5) When it dies and decomposes, its chemical substances are returned to the soil and air to be used again by plants.

SUMMARY

The vast variety of animal life makes advisable the study of particular animals as types. For the large insect group, we choose the grasshopper, which has life processes like those of other insects. The grasshopper has three body regions: head, thorax, and abdomen. Through these and their adaptations the life processes are carried out.

The grasshopper undergoes incomplete metamorphosis. It belongs to the class of *Insecta* and to the order *Orthoptera*. It is of great economic importance as a destroyer of crops.

QUESTIONS

Which is the most numerous class of animals? Are the large animals or the insects more important to man? Why? What divisions has the body of the grasshopper? In what way is he protected from his enemies? How does he get food? breathe? reproduce? Give his life history. What is metamorphosis? What kind of metamorphosis does the grasshopper undergo? To what class and to what order does the grasshopper belong? What is his economic importance?

SPECIAL TOPICS FOR DISCUSSION

1. Describe the equipment that enabled Fabre to make his many observations on insects.
2. Contrast the life of the apple tree with that of the grasshopper.
3. Compare the enemies of each.

BOOKS BY J. HENRI FABRE

Published by Dodd, Mead and Company

Bumble-Bees and Others

The Hunting Wasps

The Life of the Caterpillar

The Life of the Fly

The Mason-Bees

Published by The Macmillan Company

Insect Life

The Life and Love of the Insect

Published by The Century Company

Social Life in the Insect World

CHAPTER VII

THE STUDY OF INSECTS AND THEIR HABITS

*So, naturalists observe, a flea
Has smaller fleas that on him prey;
And these have smaller still to bite 'em,
And so proceed ad infinitum.*

—SWIFT

55. Need of Trained Workers.—Insects are so numerous and do so many different things, that it requires all the time of thousands of well-trained men and women throughout the world

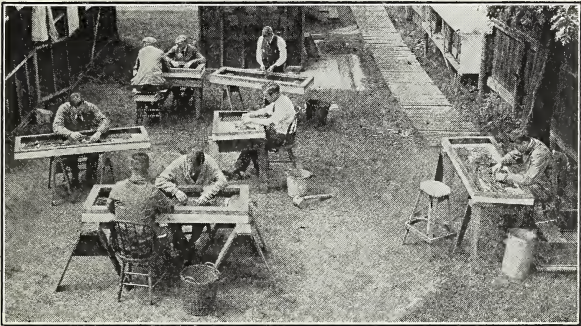


FIGURE 49. GYPSY MOTH LABORATORY IN MELROSE, MASSACHUSETTS

These trained scientists are examining the larval stage for parasites. This is part of the work of the United States Bureau of Entomology. Why is this important?

to make sure that the activities of our civilization shall not be checked by them. The United States Bureau of Entomology of the Department of Agriculture has a large force of trained workers, and each state has its own special staff of experts. The authors wrote to the man who for many years has been directing this work at Washington. This is his reply:

In your letter you asked me for suggestions as to outstanding investigations in this Bureau. Of course, we have several main projects, such as the

European corn borer, gipsy moth, the cotton boll weevil, the pink bollworm of cotton, the alfalfa weevil, and the Mexican bean beetle; but we are covering the whole field of economic entomology, not only agricultural but medical and those other aspects in which these abominable creatures interfere with human happiness and human progress. I think there will be an opportunity for every young man who feels that he has an especial aptitude for this kind of work and a special interest in it, to gain a livelihood in the future after proper training and experience, but it will never afford opportunities to gain riches or even more than a modest competence. However, the subject of entomology is so broad and offers so many fields of interest that it seems to me that there is great room for interested amateurs and that the subject of entomology is one in which many men can spend their spare time in a most interesting way. Amateur entomologists in the past have done great work. They are rare now, and it is a pity.

Sincerely yours,
L. O. Howard

You can see from this letter the tremendous importance of the work done by entomologists.

56. Main Features of Insects. — We have seen that the grasshopper, like all insects, is divided into head, thorax, and abdomen, and has three pairs of legs, and air tubes for breathing. Most insects have two pairs of wings, but this is not true of flies or of some of the simpler forms like lice, which lack wings. While there are many differences in the size of these parts, the fact that an animal has this combination of structures defines it as an insect. A study of the differences in these common parts of insects is the basis on which the following classification has been made.

57. Classification of Insects. — If we know their technical names, we can then find out more about insects in various reference books. For this reason we are giving below the most recent classification of the more common groups or *orders*, as they are called.

ORDER	PRONUNCIATION	DERIVATION	EXAMPLES
Orthoptera	ör-thöp'tēr-ä	<i>orthos</i> , straight + <i>pteron</i> , wing	grasshoppers, katydids, crickets
Hemiptera	hê-mîp'tēr-ä	<i>hemi</i> -, half + <i>pteron</i> , wing	bugs



L. O. HOWARD (1857-) was born at Rockford, Illinois. After his graduation from college, he became assistant entomologist in the Department of Agriculture at Washington. He remained in this official position until 1894, at which time he was made chief of the Bureau of Entomology.

He prepared definitions in entomology for the Century and Standard dictionaries. He is the author of *Mosquitoes — How They Live*, *The Insect Book*, *The House-Fly*, and numerous government publications. For many years he acted as the permanent secretary for the American Association for the Advancement of Science, the largest body of scientific workers in America.

Dr. Howard has devoted his main energies for the past forty years to applying the technical discoveries in entomology to human welfare.

ORDER	PRONUNCIATION	DERIVATION	EXAMPLES
Coleoptera	köl'ê-öp'tēr-ä	<i>coleos</i> , sheath + <i>pteron</i> , wing	beetles
Hymenoptera	hī'mĕn-öp'tēr-ä	<i>hymen</i> , membrane + <i>pteron</i> , wing	ants, bees, wasps, sawflies, gall wasps dragon flies
Odonata	ō-dŏn'ä-tä	toothed (<i>odontos</i> , of a tooth)	
Lepidoptera	lĕp'ĭ-dŏp'tēr-ä	<i>lepidos</i> , genitive of <i>lepis</i> , scale + <i>pteron</i> , wing	butterflies and moths
Diptera	dĭp'tēr-ä	<i>di-</i> , twice + <i>pteron</i> , wing	flies, mosquitoes
Homoptera	hō-mŏp'tēr-ä	<i>homos</i> , similar + <i>pteron</i> , wing	cicadas, aphids, scale insects

58. Importance of Insects to Man. — The numerical superiority of insects is due in large measure: (1) to their power of flight, which helps them to escape from their enemies; (2) to their small size and remarkable adaptations in color and habits which help them to avoid being eaten and enable them to live in every conceivable place and on every variety of food, some even eating tobacco and certain insecticides; and (3) to their remarkable powers of reproduction, often several thousand young being produced in a single season.

Insects eat the food which plants have made and which man needs, and a few of them are the agents that spread such destructive diseases as malaria, typhoid fever, and yellow fever. Thus they not only destroy the food and economic products of man



FIGURE 50. PROMETHEA MOTH LAYING EGGS ON THE LADY'S-SLIPPER

Can you see the eggs?

but directly cause his death. However, the argument is not wholly against insects, for some of them produce such useful articles as honey and silk.

Insects which are either helpful or harmful to man might be called economic insects. By saying that an insect has no economic importance we mean that it does not harm us by eating



FIGURE 51. A FIELD OF COTTON

This important industry is being challenged by a small insect, the boll weevil. See if you can find out how much damage it does annually to the cotton industry.

things useful to us or by spreading disease and that it does not help us in any way.

Certain insects, like the fly, that carry the germs of disease are particularly harmful, for they cause sickness and death. Certain beetles eat dead flesh or bury dead animals by tunneling under them. These insects are helpful. Others help plants that are valuable to man by carrying the pollen from one flower to another; others make honey. Such insects are useful. We should study insects in order to find out which ones are our friends and which our enemies.

59. Principal Methods of Controlling Harmful Insects. — We shall describe here only general measures for the control of insects :

(a) environmental factors, (b) poisons and traps, (c) natural enemies, and (d) preventing importation.

(a) *Environmental Factors.*

— In order to devise a definite plan for getting rid of insects, it is necessary first to understand their habits in detail. Insects that feed on roots cannot be killed by the same method as those that feed on wheat and other cereals; and in turn those that feed on the leaves of fruit trees require a different treatment from those that eat the fruit itself. Environmental factors, as temperature changes,

rainfall, winds, food supply, natural enemies, and parasites, influence very much the growth and number of insects.

One good preventive measure employed in controlling insects consists in changing the crops so that insects that feed on corn, for example, will not be able to get suitable food if clover is sown after the corn crop. The expert farmer gives careful study to the proper rotation of crops in an effort to prevent destructive insects from gaining too great headway.

Cold storage is very successful in preventing insects from developing, especially in fruit. Flour and meal

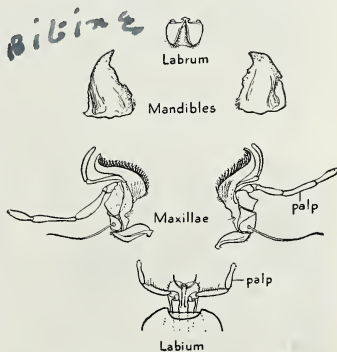


FIGURE 52. MOUTH PARTS OF A BEETLE

Notice how similar these parts are to those of the grasshopper. They are a good example of biting mouth parts.

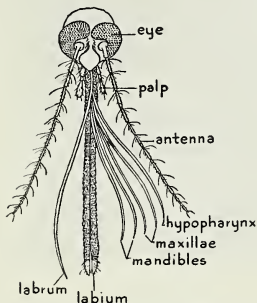


FIGURE 53. MOUTH PARTS OF A MOSQUITO

This shows in detail the sucking mouth parts.

are protected by heating sufficiently to kill the eggs or insects that may be in them.

(b) *Poisons and Traps*. — Most of the above measures can be applied only to insects that live in the soil. Poisons, repellent substances, and traps are some of the means taken to control insects that live on the plants themselves. The various insect poisons are known as *insecticides*. A good insecticide must be effective, cheap, and harmless to the insect's *host* (the victim on which the insect feeds).



U. S. Bureau of Entomology

FIGURE 54. LARVA AND ADULT OF THE MEXICAN BEAN BEETLE FEEDING ON A BEAN LEAF.

How does this harm the bean?

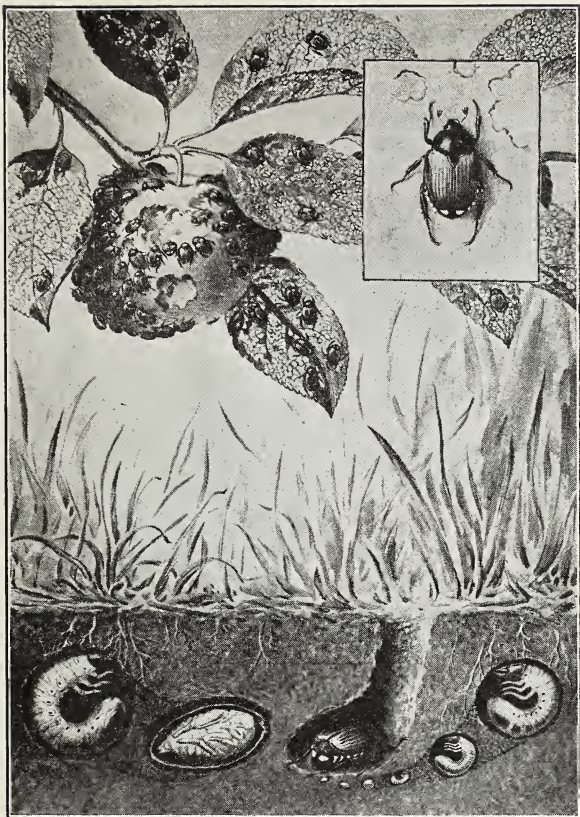
Before an expert in the control of harmful insects can suggest a method of poisoning, he must ask how the insect uses its mouth parts. Before he can satisfactorily answer this question he must know to what great order the insect belongs. In Figure 52 are shown biting mouth parts such as insects have that eat the leaf of the plant or tree. These insects can be killed by placing a stomach poison on their food. But such methods are a complete failure when one attempts

to kill the insects with sucking mouth parts as those shown in Figure 53, where the mouth parts are modified to penetrate the surface of the leaves and suck the juices from within. These insects can be killed only by poisons that enter the air tubes as vapors. Such poisons are called contact poisons.

The common "tanglefoot" and various traps are used with good results in capturing flies.

(c) *Natural Enemies*. — The natural enemies of insects are the birds and insects that prey upon them and the insects that live as parasites in them.

The United States Department of Agriculture found in Australia



U. S. Bureau of Entomology

FIGURE 55. LIFE HISTORY OF THE JAPANESE BEETLE
This is a very undesirable immigrant. How far has it spread?

a certain kind of ladybug (*Novius*) which is the natural enemy of an insect pest (cottony cushion scale) that was destroying the orange trees grown in California. This destructive scale was imported into the United States on young trees. Being freed from its natural enemies (*Novius*), which were not imported, it had increased rapidly. The prompt importation of *Novius* put an end to the increase of the cottony cushion scale, which is now of no great importance to California orange growers.



FIGURE 56. NYMPH OF SEVENTEEN-YEAR CICADA AND ADULTS

Those who live in the eastern and middle western states may expect to see the adult in 1936. There may be other kinds in each vicinity.

Entomologists throughout the world are joining ranks in the war against insects. Parasites which prey upon insects and keep their numbers down in one country are constantly being drafted by scientists for use in the fight against the imported pests of another country.

The United States has had an expert in Mexico in search of parasites of the Mexican bean beetle and the Mexican fruit fly. Two experts have been in Japan seeking the parasites of the Japanese beetle and the gipsy moth. Others have been in Hungary, India, and France. The experts of all these countries are also studying insect pests and recording their discoveries in books, scientific papers, and government bulletins so that all the world may take advantage of them.

60. Cicada. — You have probably all heard of the “seventeen-year locusts,” that come in swarms for a season. The name is

given them because the nymphs, the growing stage in the insect's metamorphosis, remain in the ground, feeding on roots for seventeen years before they emerge. There is another kind of cicada that remains in the ground for thirteen years. It lives in the southern states.

At the end of thirteen or seventeen years, generally in

the month of May, the nymphs crawl out of the ground, climb trees or fences, and molt into adult cicadas (sī-kā'dā). The adult females lay their eggs in tender shoots of trees, causing the shoots to die. The young cicadas, after hatching in the shoot of the tree,



FIGURE 57. DIAGRAM OF CICADA SHOWING FORM OF SUCKING MOUTH PARTS

How does it feed?

go into the ground and begin their long period of larval existence. These cicadas are usually found in limited areas, but in those areas they are very numerous and destructive.

The cicadas which we hear every summer are of another kind, the nymphs of which live in the ground for two years. As there are two broods of this species that appear in alternate years, the number does not seem to vary from year to year. Birds do much towards destroying them, the kingbird, sparrow hawk, butcher bird, and great-crested flycatcher being their most common enemies.



FIGURE 58. GOLDEN BEETLES

This beetle is a fine example of the Coleoptera. How does it differ from a grasshopper?

61. Coleoptera. — The beetles have hard wings and are generally noisy fliers. The first pair of wings meets in a straight line

down the back. The second pair consists of thin membrane. The mouth parts are adapted for hard biting. Among the harmful beetles are many wood borers, the May beetles, potato beetles, asparagus beetles, and boll weevils. Two of the beneficial beetles are the ladybug, which feeds on destructive and

harmful insects, and the carrion beetle, which feeds on dead animals.

Hop growers appreciate the value of both the ladybug larvæ and the adult ladybugs on their vines, as they destroy the harmful hop lice.

The beetle fortunately has numerous bird enemies, of which the most important are the ring-necked pheasant recently introduced, the rose-breasted grosbeak, and the quail, which feeds particularly on potato beetles. The English sparrow, cuckoo, and kingbird feed on weevils. Robins, blackbirds, and crows eat white grubs, the larval



FIGURE 59. CEDAR WAXWING FEEDING ITS YOUNG

Birds are very important in helping to keep insects from becoming too numerous.

stage of May beetles. The woodpeckers catch great numbers of borers by digging holes in the trees where the borers are tunneling.

62. The Potato Beetle. — The "potato bug" was first found in Colorado feeding on wild plants of the potato family, whence its name, Colorado beetle. It gradually made its way east from one potato patch to another, being helped by the wild plants of the potato family that grew where there were no potatoes. These beetles were also carried on potatoes by trains that in a few hours took them hundreds of miles. They arrived in New York State in 1872.

The potato beetle feeds on the foliage of the potato plant, and injures the size and quality of the tubers. The injury is due to the fact that most of the starch stored in the tuber is produced in the leaves, and when the leaves are destroyed, the amount of starch available for the tuber is lessened. Spraying must be carried on wherever potatoes are grown, to insure a good crop.

Life History. — The adult potato beetles pass the winter in the ground. In the spring they crawl out of the ground and the females lay their orange-colored eggs on the under side of the leaves of the young potato plants. In about a week or ten days the eggs hatch and the larvæ eat ravenously. In two or three weeks the larvæ reach their full size. They then dig into the ground, where they pupate for two weeks or longer, depending on the temperature. At the end of this period, they emerge as adults and the females lay their eggs on the late potatoes for a second generation. The eggs hatch into larvæ, the larvæ pupate in the ground, and the adults of the second generation emerge in the fall. At the beginning of the cold weather the adults enter the ground and hibernate.¹

Natural Enemies. — Fortunately the potato beetle has many natural enemies. Adult lady beetles, popularly called "lady-bugs," and their larvæ kill many of them. The tachina flies lay eggs on the potato beetle larvæ and the young tachina flies in the form of larvæ burrow into the bodies of the beetle larvæ, killing

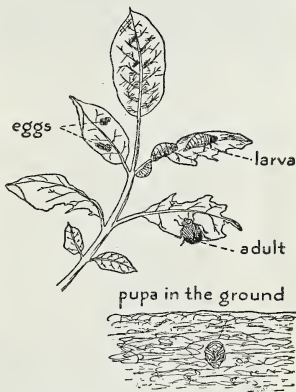


FIGURE 60. LIFE HISTORY OF THE POTATO BEETLE

What are the several stages? In which stages are the leaves eaten? How does this harm the potato plant?

¹ To hibernate (hī'bēr-nāt) is to pass the winter in a state of inactivity.

them in great numbers. Birds, toads, snakes, and skunks also are enemies of potato beetles and take a heavy toll of them.

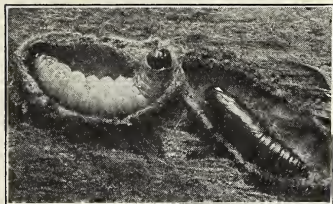


FIGURE 61. CODLING MOTH, SHOWING LARVA AND PUPA STAGES

63. The Codling Moth. — The codling moth, which we discussed in Chapter I in connection with the apple tree, is the most destructive of the Lepidoptera. The larvæ spend the winter in the cocoon, pupate in the spring, and emerge as adult moths when the early apple trees are

blooming. The moths lay their eggs on the young apples about the time the petals of the blossoms fall, and when the larvæ hatch, they begin to eat the growing apples, causing many to drop to the ground, lessening the size and injuring the quality of others, and making nearly all the apples they enter unfit for human consumption.

In one year the injury done by the codling moth to the apple and pear industry in New York State alone amounted to



Ewing Galloway

FIGURE 62. THE ANNUAL BANQUET OF THE CLOTHES MOTHS ASSOCIATION

What are you going to do to prevent this annual feast?

\$3,000,000. By applying a spray containing some poison just after the petals have fallen, the codling moths may be destroyed. The spray should not be used while the blossoms are on the tree because then the helpful bees which visit them are killed and no harm is done to the destructive codling moths that come later.

64. Clothes Moths.— You have probably all seen small moths with pointed and fringed wings, flitting about your clothes closet. The adults emerge from May to August, eat no food, and after depositing their eggs on woolen material, soon die. It takes three weeks for the transformation of the pupa into the adult. More than one generation may arise in a season.

The white, naked larva is about a half inch long and feeds on furs, feathers, hair, woolen materials, and museum specimens. The destructiveness of these larvæ has resulted in the invention of many remedies. A full discussion of these will be found in *Farmers' Bulletin* No.



U. S. Department of Agriculture

FIGURE 63. TENT OF THE TENT CATERPILLAR

This larva manufactures a silklike tent. At what time of the day does the larva occupy its tent? Upon what does it feed?

1353. A few of the more important are the following: (1) constant watchfulness, for no treatment that kills the larva already in fabrics will have any lasting effects in keeping other clothes moths from depositing their eggs if the material is left exposed; (2) thorough brushing and beating if possible and placing the clothes in the sun before any treatment is applied; (3) careful wrapping in unbroken paper, especially newspaper; (4) naphthalene and camphor for use in tight chests and trunks.

65. Tent Caterpillars.— The caterpillars that spin webs in the trees during late spring are known as tent caterpillars (Figure

63). The larvæ grow to maturity in about a month and during this time they feed voraciously on the leaves of trees.

Some of the tent caterpillars pass the winter in the pupa stage, and others hatch in the spring from the fall batch of eggs.

66. **Silkworms.** — Silkworms, like tent caterpillars, belong to the group of spinning moths. Yet the former are valuable friends to man, the latter serious enemies. The silkworm larvæ feed



Bunny Galloway

FIGURE 64. SILKWORM INDUSTRY IN KASHMIR, INDIA

65,000 families work under government regulation. This picture shows cocoons drying in the sun.

preferably on mulberry leaves, although they will eat the leaves of the Osage orange.

After the larvæ feed for about a month, they spin their cocoons. The material for the cocoon is manufactured in the silk glands which open directly under the mouth. It takes three or four days for the larva to make its cocoon, which is constructed of a smooth thread usually more than one thousand feet long. In a week or two pupation ends and the adult escapes from its silken home by moistening the cement between the silk threads on one end of the cocoon.

It usually takes about three thousand cocoons to make a pound of raw silk and about ninety cocoon fibers are required to make a thread of sewing silk. Twenty-five to fifty thousand cocoons are used in securing enough material for a silk dress.

Those engaged in the silk-raising industry need a detailed understanding of the habits of this domesticated insect. The cocoons from which the silken threads are secured are baked or steamed two or three days after the larvæ have completed them. This process kills the pupa, for cocoons from which the adults have escaped are unsatisfactory for the manufacture of silk.

67. An Immigrant Pest. — The European corn borer was introduced into the United States in 1909 and 1910 in broom corn imported from Hungary and Italy. This insect is a member of the moth family or Lepidoptera and is injurious in the caterpillar or larval stage. Since its introduction it has spread over more than 7696 square miles, and has been found in 185 species of plants in the United States. This pest is destructive to corn, beans, beets, cotton, potatoes, Swiss chard, and many other of the food plants of man and animals, also to dahlias, hops, and sunflowers.

The European corn borer spends the winter in the tunnel made in the plant upon which it has been feeding. In April or May the borer, which is a caterpillar, spins a cocoon in the tunnel and in about nineteen days develops into the adult moth. After mating, the female deposits her eggs on the young corn shoots in small masses, each egg overlapping the adjoining egg in the manner of shingles. The females deposit about 350 eggs, on an average, but some lay more than a thousand. These eggs hatch in about seven days. The young borer soon begins to eat its way into the inside of the plant and within fifty days has again grown into an adult. Thus a second brood is ready to be hatched.

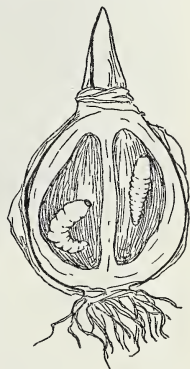


FIGURE 65. BEETLE GRUBS IN A BULB

The females of this later generation lay more eggs, usually about 450, which are frequently deposited on or near the forming



FIGURE 66. THE CORN BORER

At left, the borer at work; at right, the external signs of its work.

ears of corn. These eggs hatch in seven days and the borers begin their destructive feeding. The caterpillars of this second generation are the ones that pass the winter in the tunnels of the



U. S. Bureau of Entomology

FIGURE 67. A FIELD OF CORN RUINED BY EUROPEAN CORN BORERS

corn or other plant on which they have been feeding.

The name *corn borer* is given to the larvæ of several different kinds of insects that burrow into the stalks and ears of corn as well as into flowering plants and weeds.

The seriousness of the destruction caused by the European corn borer has led the United States

Department of Agriculture to place strict regulation on the importation from foreign territory of plants likely to contain this insect.

FIELD, LABORATORY, OR HOME STUDY OF MOTHS AND CATERPILLARS

These insects are easily collected and are interesting to study. From late in the spring until October you can find larvæ and pupæ. Some of the leaves upon which the larvæ are feeding should be collected.

The larvæ should be placed in jars provided with moist soil and some leaves. Arrange the cocoons and pupæ which you find as suggested below. Copy the table and make your entries on the copy. Do not mark your book.

COCOON			PUPA			
Spun with silk only	Spun with a leaf	Spun with hair	Without cocoon	Suspended from one end	Suspended from one loop	Parasitized

Tent caterpillars spin cocoons and turn into small brown moths. Celery "worms" hang in a loop and form a black, swallowtail butterfly which feeds on the nectar of lilacs and the rhododendrons of city parks.

The black spiny caterpillars of the willows and elms hang free from the knot of silk and form the mourning cloak butterfly.

Tomato "worms" burrow into the ground and form a large-bodied, small-winged moth, a sphinx moth.

68. Lice. — Lice are small, wingless insects. The mouth parts of some are adapted for piercing and sucking, but the bird lice have nipper-like mandibles for biting instead of sucking. The bird lice feed only on the hairs and feathers and not on the blood as do the sucking lice. The feet of lice are provided with large curved claws enabling them to cling to their victims.

The head louse that afflicts man deposits the eggs, about sixty in number, on the hairs of the head. The eggs usually hatch in six days. Head lice, notwithstanding the progress of civilization, are the most important of the external human parasites. They are commonly found in logging camps, jails, ships, in fact wherever there is close association with people who are dirty.

The body louse is an insect which differs from the head louse. It lives on the clothing and deposits its eggs there. It has been conclusively proved that the body louse is an important carrier of the germs of typhus fever, relapsing fever, and trench fever. It is possible that as lice move from one rodent¹ to another they may carry the germs of the dreaded bubonic plague, if their host harbors these germs.

Temporary lousiness cannot be prevented if there is association with unclean and careless companions. Lice are spread by the common use of combs and brushes and by borrowed hats and caps. Body lice are scattered from person to person through the clothes and bed linen.

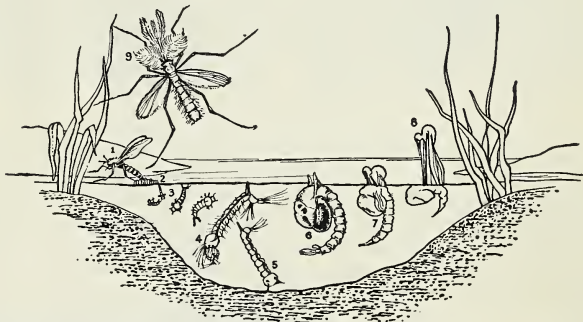


FIGURE 68. DIAGRAM TO SHOW LIFE HISTORY AND HABITAT OF MOSQUITO

69. Mosquitoes. — The order *Diptera* includes some of the worst insect enemies that afflict mankind. It includes, besides house flies and mosquitoes, the botfly, stable fly, and cheese skipper; also the beneficial bee fly, wasp fly, and tachina fly.

The common mosquito lays from two hundred to four hundred eggs in a raft-like cluster on the surface of the water in any stagnant pool or rainwater barrel. These eggs are usually laid

¹ Rodents are gnawing animals, such as rats, mice, and ground squirrels (see § 150).

early in the morning and, in favorable weather, hatch within twenty-four hours. The wigglers (larvæ) keep to the surface when breathing but swim freely in the water for food. Food is brought to the mouth by vibrating cilia (hairlike processes), which keep a current of water passing near them. After seven days they become pupæ, which, unlike most other pupæ, can move about. The pupa stage lasts for two days; then the adult emerges and flies away after its wings are dried.

The time of these changes from egg to larva, from larva to pupa, and from pupa to adult depends on the temperature. Warm weather shortens the time and cold weather lengthens it.

In the United States there are three distinct kinds of mosquitoes. (1) The common mosquito is known by the technical name of *Culex* (kū'lěks). It is not certain that the *Culex* carries in its body any disease germs harmful to man, but it is a blood-sucker and a source of great annoyance to those who frequent the woods or seashore during the summer, and makes some districts uninhabitable. (2) *Anopheles* (ā-nŏf'ē-lēz) is the scientific name of a second kind of mosquito, which is also generally distributed, but is not so numerous as the *Culex*. The *Anopheles* often carries in its body *malaria* germs. (3) *Aedes*, formerly known as *Stegomyia* (stěg'ō-mī'yā), is a mosquito common in the southern part of the United States. It is the insect that carries yellow fever germs from one person to another.

It is fortunate for man that these three mosquitoes have so many enemies. The wigglers are preyed upon by the larvæ of dragon flies, by small fish, and by water beetles; the adults are eaten by nighthawks, martins, bats, and dragon flies. Certain diseases caused by plants (bacteria; see Chapter XXV) attack the adults and kill them in great numbers.

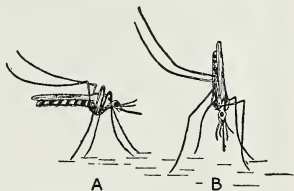


FIGURE 69. CULEX AND ANOPHELES CONTRASTED

Culex (A) and *Anopheles* (B) are shown at rest.

The number of mosquitoes can be greatly reduced by destroying their natural breeding places in old rain barrels, watering troughs, boxes that may hold water, pails, eaves, and sink holes. The larger breeding places are sluggish streams and swamps. Draining these is the most effective method of preventing mosquitoes from laying their eggs in such localities. When this is not possible,

the surface of the water may be covered with kerosene or other oil, which kills the larvæ by preventing them from getting oxygen from the air.

70. The House Fly. — Because of its filthy habits of breeding and because it crawls over our food, the house fly is now recognized as a dangerous disease carrier and one of our worst enemies.

Each female lays from one hundred to one hundred and sixty eggs in stable manure or other refuse. The eggs hatch in a day or so into legless

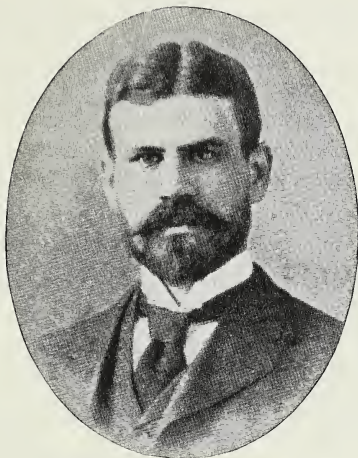


FIGURE 70. A DRAGON FLY

This is one of the insects that feed on adult mosquitoes.

larvæ. In five to seven days, depending on the temperature and the food supply, the larvæ are full grown. They then pupate for another five to seven days. At the end of this time the adults emerge as mature flies ready to lay eggs for another generation. This continues until cold weather puts an end to their activities. Enough generations are produced every year so that a single female born in the spring could have a million descendants by October if numerous enemies did not make this impossible.

The House Fly and Typhoid Fever. — Typhoid fever is caused by germs that live in the walls of the intestine. The germs, then, will be found in sewage. Flies walk in sewage searching for food. The sticky feet and hairy bodies pick up and hold all kinds of



JESSE LAZEAR. In 1900, Major Walter Reed and Drs. James Carroll, Aristides Agramonte, and Jesse W. Lazear were appointed to study sanitary conditions in Cuba. They gave special attention to yellow fever, which was prevalent. There was some evidence connecting the mosquito known as *Aedes calopus* with this scourge.

The mosquitoes were allowed to suck the blood of a yellow fever patient and were then placed on susceptible persons. Carroll was the first volunteer to succumb to the infection. He recovered, but died seven years later from complications following the attack of yellow fever. Dr. Lazear also became infected, and died on September 25, 1900. Twelve soldiers who volunteered were also infected by mosquitoes.

The facts established by the commission are: (1) yellow fever is acquired *only* through the bite of the female *Aedes calopus*; (2) the mosquito to become infected must bite a yellow fever patient during the first three to five days of the disease; (3) at least twelve days must elapse, after the mosquito has obtained blood from a yellow fever patient, before it can infect another person.

germs. Some one leaves a screen door open and flies get into the dining room. The flies alight on the food. Some of the germs of typhoid fever may thus be left on the food, and one of the family may eat the food that the flies have polluted.

Methods of Control. — The few house flies that survive the winter are responsible for the millions that swarm about in the summer. Their numbers may be reduced by several methods :

1. Begin early to kill the flies that are seen.

2. Remove all manure piles and have a general cleaning up of all refuse, thus destroying their breeding places.

3. Put fly traps on the covers of garbage cans to entrap all those that hatch as well as adults that go in to feed.

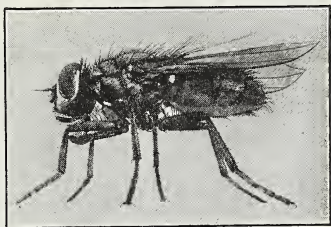
4. Keep many fly traps in operation in or about the house during the time of year that flies are active.

5. Poison those that do come into the house and keep fly paper ready for them at all times.

71. Parasitism. — If a plant or animal lives in or on a living plant or animal, it is an example of parasitism. If a parasite attacks the outside of an animal, as the louse does, it is called an external parasite. If it feeds on the inside of an animal, as in the case of the tachina-fly larva, it is called an internal parasite.

72. Parasitic Flies. — This group of insects is decidedly beneficial.

The *tachina fly*, which is very beneficial to man, somewhat resembles the house fly, but has differences that may be clearly seen. It has long bristles on the abdomen and the bristles of the antennæ are bare. The tachina fly lays its eggs on tent caterpillars, army worms, and many other destructive caterpillars. After these eggs are hatched, the tachina larvæ bore into the bodies of the caterpillars and feed upon them until they consume



American Museum of Natural History

FIGURE 71. THE COMMON HOUSE FLY

them. Many kinds of caterpillars are held in check by the activities of these tachina flies.

One of the larger parasitic flies is known as *Thalessa* (Figure

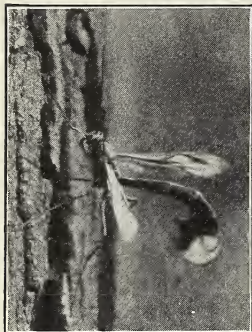


FIGURE 72. *THALESSA* LAYING EGGS

What will the young feed on?

72). With long, thread-like drills this parasitic insect bores holes in trees and lays an egg at the bottom of each hole. The egg is usually laid near the burrow of one of the larger tree borers, *Tremex* (Figure 73). The larva *Thalessa* makes its way along the burrow of the *Tremex* borer and fastens itself to the body of the borer, upon which it feeds. If the borer eats its way to the outside of the tree, the adult *Thalessa* emerges, ready to produce another generation of larvæ which will destroy more borers. But if *Thalessa* parasites kill the *Tremex* borer before it has eaten its way

through the hard wood, all die together because *Thalessa* cannot cut an opening for itself.

73. Coloration and Mimicry among Insects. — If you have ever tried to catch grasshoppers, you know how difficult it is to see them when they are not in motion. The colors of the wings and upper parts blend with the grass on which they feed. These colors are said to protect the grasshopper, and the expression *protective coloration* is used to describe this condition.

Butterflies and moths show protective coloration, especially in those forms that have the upper surface of the wings colored similarly to the trunks of trees on which the insects rest. Such dull colors are effective in obscuring them. The contrast in color is striking in

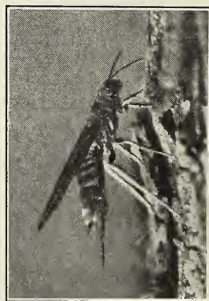


FIGURE 73. *TREMEX*

all of these if we compare the brilliant colors seen on the hind wings when the insect is flying.

An insect whose colors enable it to hide and lie in wait, making it more successful in catching its prey, is said to exhibit *aggressive coloration*. Some insects that are believed to be unpleasant to taste have bright colors on their bodies to warn the animals that prey on insects that they are unsuitable as food. The conspicuous bands of color on wasps are said to warn animals that these

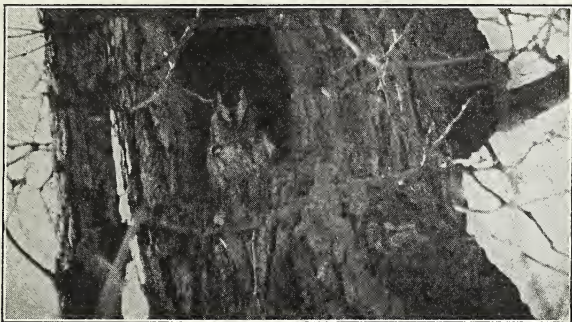


FIGURE 74. A SCREECH OWL RESTING IN A LARGE OPENING IN AN OAK TREE
Do the markings on the bird resemble the markings on the tree? What is this resemblance called? Is it true of other animals?

insects have a dangerous sting. Such insects show *warning coloration*.

The brightly colored insects often have imitators which have neither an unpleasant taste nor a dangerous sting. This similarity is known as *mimicry*.

SUMMARY

The number and variety of insects are so great that this is called the Age of Insects. Many that destroy food-products and attack man directly are harmful, but some, like the bee, are helpful. Scientists have made an elaborate classification of insects, but the orders we are most interested in are the Homoptera (locusts), Coleoptera (beetles), Lepidoptera (moths and butterflies), Diptera (flies and mosquitoes), Suctoria (lice and fleas), Orthoptera (grasshoppers), and Hymenoptera (bees and ants).

The potato beetle, codling moth, tent caterpillar, corn borer, and boll weevil are among the insects that do the most damage. It is hard to estimate the loss caused to our food-products each year by these five. The clothes moth ruins thousands of dollars' worth of clothing and furs each year. Lice and fleas are annoying pests. Mosquitoes and house flies are common carriers of disease. On the other hand silkworms furnish us with valuable clothing. The tachina fly and other parasitic flies are beneficial to man.

There are many ways of controlling insects. The federal and state governments spend huge sums each year in this work. Rotation of crops helps to keep the pests from increasing. There are also many poisons, spread usually by spraying. Birds are natural enemies of insects. Many insects escape their enemies because of their protective coloration.

FIELD PROJECTS

Every animal or plant must adapt itself to the winter season or perish. Some insects live through the winter in the egg stage, as in the case of the tent caterpillar. Others, like the Isabella caterpillar, pass the winter as larvæ. The cicada escapes the cold deep in the ground in the nymph form, while the cecropia moth is safe in a cocoon as a pupa. The mourning cloak butterfly is hanging in some protected place, in a barn or shed. The monarch butterfly has migrated to the southern states and thus escapes our severe winter weather.

How many other examples can you find? Favorable places for these various groups are old board piles and lumber piles, old buildings, fence rows, hedges, and vine tangles. Bring into class all cocoons, egg masses, chrysalids, larvæ, and in fact any form of insect that may prove to be alive.

Individual members of the class may select one of the following problems to be studied and written up.

1. What do you find in searching the leaves of hollow stumps and logs in the woods?
2. What do you find in searching the lilac trees and tangles?
3. What do you find in searching the hedgerows and the vines that climb on buildings?
4. What do you find in searching lumber piles and board piles?
5. What do you find in searching old buildings, barns, sheds, and other protected spots?
6. Make a terrarium for confining all the specimens that are brought in, but keep it outside on the window ledge.
7. Sketch a landscape, roughly, which will show the area you covered, and on it locate the positions of the forms you found.
8. Identify and classify your specimens with the aid of insect books and government agricultural reports.

QUESTIONS

What is an insect? Are insects helpful or harmful to man? Illustrate your answer. What is meant by *economic insects*? What are some of the best-known orders of insects? Name some common representatives of each. What insects do most harm to our food? to our clothes? Are mosquitoes and flies dangerous or merely annoying? Name two kinds of lice. What methods have the federal and state governments adopted to control the spread of insect pests?

REFERENCES

- Crary, *Field Zoölogy*, Chapter X (out of print)
 Fabre, *The Life of the Fly*, Dodd, Mead and Company
 Fabre, *The Life of the Caterpillar*, Dodd, Mead and Company
 Hewitt, *House Fly*, The Macmillan Company
 Hodge, *Nature Study and Life*, Chapter XV, Ginn and Company
 Howard, *Fighting the Insects*, The Macmillan Company
 Howard, *House Fly. Disease Carriers*, Ohio State Department of Health
 Kellogg, *Animals and Man*, Chapter XV (out of print)
 Ross, *The Reduction of Domestic Mosquitoes*, J. B. Lippincott Company
 Smith, *Our Insect Friends and Enemies*, J. B. Lippincott Company

CHAPTER VIII

MOTHS, BEES, AND ANTS

*The pedigree of honey
Does not concern the bee;
A clover, any time, to him
Is aristocracy.*

—EMILY DICKINSON

74. Moths and Butterflies. — In the preceding chapter we studied the codling moth, clothes moth, tent caterpillar, and corn borer. But there are also many others, including tussock moths,



FIGURE 75. MONARCH BUTTERFLY GETTING NECTAR FROM A THISTLE

gypsy moths, brown-tail moths, cut-worms, canker worms, and cottonboll worms. Many insects develop from larvæ that do no particular harm, and many of them, like the bees, help in pollination.

Butterflies are among the most attractive insects. As the butterfly goes from flower to flower, its head brushes against the pollen, which is thus distributed, making it possible for flowers to grow seeds. Other butterflies are harmful. Among the more strikingly colored butterflies are the black swal-

lowtail, the larvæ of which feed on celery, parsley, and carrots; and the milkweed or monarch butterfly.

75. The Complete Metamorphosis of the Monarch Butterfly. — Along in June, when warm weather comes to the northern

states, the monarch butterfly arrives from the South. The females begin at once to lay eggs on milkweed plants. The eggs hatch in a few days — the time depending on the temperature — into caterpillars that feed on the leaves of the milkweeds. Each caterpillar has three pairs of jointed legs near the head and five pairs of leg-like structures along the posterior region that serve for clinging. The caterpillar (larva) molts and each time



FIGURE 76. LIFE HISTORY OF MONARCH BUTTERFLY

Top row: Full grown larva; ready for fourth molt; pupa complete

Bottom row: Resting pupa; adult emerged; wings expanded

grows larger but does not show any signs of wings like the grasshopper. It is merely a larger caterpillar.

Just before the fourth molt it attaches itself to a leaf or stem and hangs by a knot of silk with its head down for a few days until it molts for the fourth time. After this molt it is a pupa without legs or mouth parts. It is yellowish green, with golden spots. During this stage there is a striking change taking place inside the green covering. Wings, new legs, different mouth parts with a long, coiled tongue, and a nervous system of a different form are growing into working order while this pupa hangs so quietly. After a few days the green pupa case breaks open and the adult

crawls out with the wings crumpled. Within a few hours the wings expand and smooth out their wrinkles, and the butterfly is ready to fly away to feed on the nectar of flowers. This development is called *complete metamorphosis*.

Complete metamorphosis may be defined as the series of changes through which the insect passes from egg into caterpillar or larva, then into pupa, and finally into full-grown butterfly. Ants, bees, butterflies, beetles, and certain other insects undergo a complete metamorphosis.

LABORATORY STUDY

The adult monarch butterfly has the body divided into head, thorax, and abdomen. How do these parts compare in size with the same regions in the grasshopper? Compare the legs and wings with those of the grasshopper. Which of these two insects is better adapted to flying? to jumping? Draw the entire animal. Draw wings and legs.

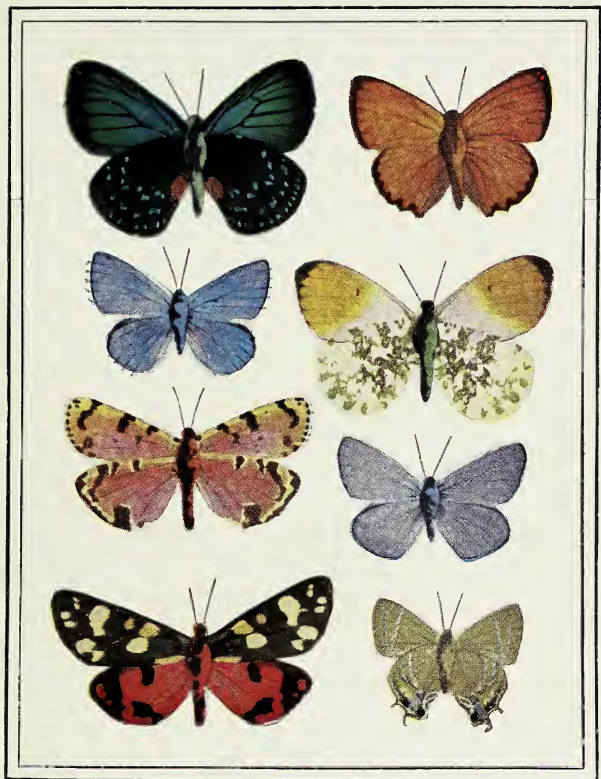
Gently rub the finger on the wing. As the dust comes off, the wing looks more like the wing of a fly or bee. The lines that run lengthwise of the wing are the veins. Draw the wing.

Observe the mouth parts of the caterpillar to see how they are adapted to obtaining food. Notice the antennæ or feelers and the upper and lower lips. Compare these with the corresponding parts of the grasshopper.

The mouth parts of the butterfly are united into a single long tube, the coiled tongue-like structure called the proboscis (prō-bōs'is). Unroll it and see how its length compares with the length of the body. The butterfly uses the proboscis to suck nectar from flowers. Compare these mouth parts with those of the grasshopper.

76. Migrations of the Monarch Butterfly. — This is the way Professor Comstock tells the story of the monarch's migrations in his book *How to Know the Butterflies*.

The male monarch is the dandy among butterflies *par excellence*. He is not only trim in figure and gorgeous in color, but on each hind wing he carries a black satchet bag for the allurements of his lady-love. And she is as brilliant as he, but lacks the perfume pockets. "I am the monarch of all I survey" is exemplified in the confident, serene flight of this butterfly; the species is nauseous to the birds in both the caterpillar and adult stages, and by their bold actions they show the result of this immunity. But the monarchs have troubles of their own, even if the bird problem is eliminated. Undisturbed, they spread and flourished in their native tropic America, until it became a



The Butterfly Box, Inc.

"BRIGHT BUTTERFLIES
FLUTTERED THEIR VANS, AZURE AND GREEN AND GOLD."

These hair streak, copper, orange tip, and blue butterflies are found from the Gulf of Mexico to Canada.

question of sufficient food-plants to nourish their numerous progeny. Because of this they began pushing farther north and south during the seasons of plant growth. As they could not endure the northern winter they came north for the summer and went back in the autumn. This northern migration is accomplished thus: the mother butterfly follows the spring northward as it advances as far as she finds milkweed sprouting; there she deposits her eggs, from which hatch individuals that carry on the journey, and in their turn lay eggs as far north as possible. Thus generation after generation pushes on until late in the season we hear of them as far north as Hudson Bay. As the cool weather approaches these emigrant butterflies gather in great flocks and fly back to the South. It is quite impossible for us to understand how the flocks of butterflies are guided in their migrations. None of them are travel-wise, like the leaders of the bird flocks, but still they follow their direction as steadily as the wind will allow. Nor is the monarch satisfied with these journeys to the north and south; it is the strongest flyer of all the butterflies and does not hesitate to try its fortune over the seas, and has been found five hundred miles from shore. Either by flight or as stow-aways in vessels it has pressed eastward to Europe and westward to the isles of the Pacific. Well is it named the monarch, for it is the most daring butterfly that we know, pushing back its geographical boundaries to the edge of the Arctic zone, and exploring leisurely the seas of the Occident and Orient. In the North there is but one brood during the summer, while in the South there are many more. No hibernating specimen has ever been found.

Perhaps some present-day high school student may find out how they are guided, or find one hibernating.

77. Enemies of Moths and Butterflies. — Like most insects, butterflies have numerous enemies without which they would soon become a scourge. Chief among these enemies are the parasitic flies (§ 72), the females of which lay their eggs on the bodies of many kinds of caterpillars (larval butterflies). When these eggs hatch, the larvæ burrow their way into the body of the caterpillar, feeding upon the tissue of their host.

These parasitic larvæ so weaken the caterpillar that it dies. The larvæ grow rapidly and before the caterpillar dies they reach the stage at which they turn into pupæ. When they are ready to pupate, they eat their way out of the body of the caterpillar and spin a cocoon which in some cases remains attached to the body of the caterpillar (Figure 77).

Other enemies of butterflies and moths are the birds. Many

birds live entirely upon caterpillars and we find birds that seek them as food in all stages of their development and growth. The eggs laid on the twigs and trunks of trees are eaten by chickadees, nuthatches, brown creepers, and woodpeckers. The larvæ are eaten by many birds, notably by cuckoos, bluebirds, wrens, blackbirds, orioles, blue jays, crows, and house sparrows. The

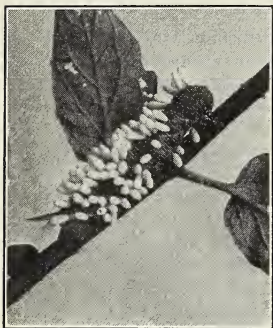


FIGURE 77. YOUNG TOBACCO
"WORM"

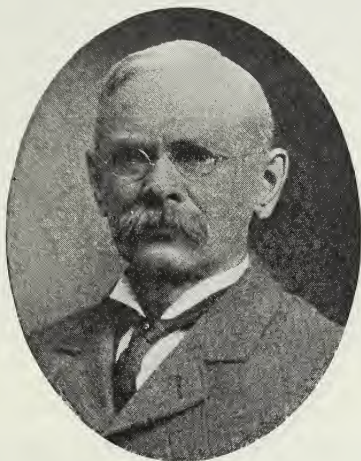
This is a caterpillar. What are the white bodies attached to its skin? Where did they come from? Do they harm the caterpillar?

cocoons and pupæ are sought by the chickadees, woodpeckers, nuthatches, and brown creepers. The adult insects are preyed upon by house sparrows, chipping sparrows, and the whole group of flycatchers, including the kingbirds and phœbes.

78. Bees.—Contrasted with the destructive moths and butterflies, we find the bees the most valuable of all insects to man. The honeybee and the bumblebee are economically the most important of the group. The honeybee is valuable for its honey and wax and as a distributor of the pollen which is necessary to produce seed. The bumblebee is valuable mainly as a distributor of pollen.

Honeybees afford a very interesting example of community life among insects. In the wild state they live in trees and caves. All wild honeybees in this country have escaped from hives. In a honeybee colony there are three classes of bees—the perfect females or queens, the males or drones, and the imperfect females or workers (Figure 80). There are generally one queen, a few hundred drones, and twenty to fifty thousand workers in a colony.

The queen alone lays eggs. She can lay an unfertilized egg which hatches into a drone or she can lay an egg which is fertilized. This fertilized egg hatches into a queen or a worker, according to the food and the size of the cell which are provided by the workers.



JOHN HENRY COMSTOCK (1849-1931) was born in Janesville, Wisconsin. He graduated from Cornell University in 1874, and did graduate work at Yale and in Leipzig. His great interest was the study of insects. He was an authority on many phases of insect study.

He aided many young men who showed an interest in insect study to graduate from college. His enthusiasm has passed on to hundreds of young men who are now aiding the world in its war on insect pests. He tried to make the study of insects as popular as the study of birds and flowers. In writing his book *How to Know the Butterflies*, he was assisted by his wife, Anna Botsford Comstock, who has written many books of her own. The best-known book of the Comstocks is *A Manual for the Study of Insects*.

Professor Comstock was the first professor of entomology in an American university.



LORENZO LORRAINE LANGSTROTH (1810-1895) graduated from Yale in 1831. Later he studied for the ministry and followed that calling. Still later he became a teacher. He was a beekeeper and made a special study of bees. He was an interesting writer and is known for his book *The Hive and the Honey Bee*.

He is most widely known because he invented the movable frame used in beekeeping today. Before his invention of this most useful device, bees were kept in sections of hollow logs or in boxes that could not be opened. The hives with movable frames can be opened and the frames examined. In this way the beekeeper may see the condition of his bees and control them in a way unheard of before the days of Langstroth. His invention made possible an industry that does a \$12,000,000 business annually.



FIGURE 78. THE SKUNK APPROACHING A HIVE OF BEES

The skunk scratches on the hive, the bees come out and are eaten by the skunk. Although stung repeatedly, the skunk is not driven away.

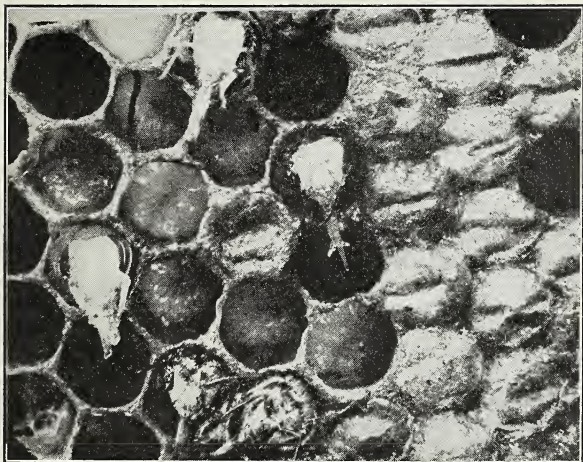


FIGURE 79. HONEYBEE BROOD COMB

The caps were cut away to show three young bees before they are ready to hatch. Two young bees ready for business (shown in lower part of picture) are escaping from their cells.

Thus the decision as to whether the young bee shall be a queen or a worker rests with the workers themselves. They also have the power to supersede the queen, or to raise a new queen in case



FIGURE 80. HONEYBEES

a, worker; *b*, queen; *c*, drone. (Twice natural size.) Which one makes the honey?

of the sudden death of the old one. These powers are intrusted to the workers — the great majority.

The eggs are placed by the queen in cells (Figure 79), and after hatching are fed by the young workers, called nurses. The larva (Figure 81) is fairly bathed in food. In a few days the larva weaves a cocoon and changes to a pupa. The workers now cap over the cell with wax, and in about twenty-one days the young bee cuts away the cap and crawls out — an adult provided with the four wings, mouth parts, antennæ, and six legs of the honeybee (Figures 80, 82, and 84).

Workers are provided with the sting, a weapon both of defense and offense (Figure 83). The queen has a small sting and the drones have none. When a bee stings a large animal, the sting

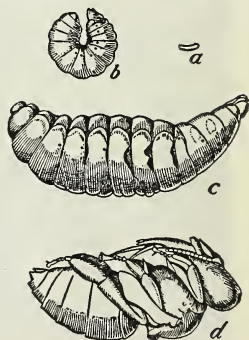


FIGURE 81. GROWTH OF THE HONEYBEE

a, egg; *b*, young larva; *c*, old larva; *d*, pupa.

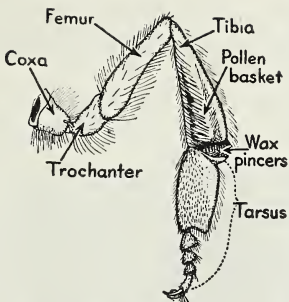
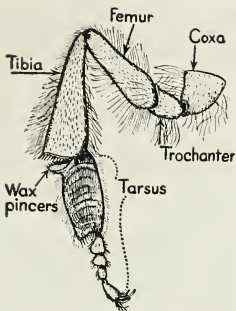


FIGURE 82. HIND LEG OF WORKER BEE
At left, inner surface, at right, outer surface, of left hind leg.

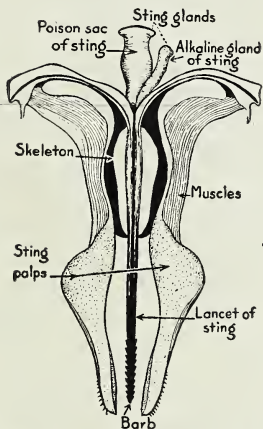


FIGURE 83. THE BEE'S STING MAGNIFIED

In addition to the barbs, there is a small amount of formic acid. Is it easy to pull out the sting? How does the sting serve for protection? Is this an adaptation?

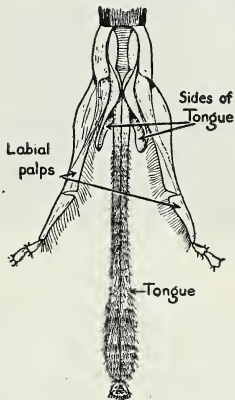


FIGURE 84. TONGUE OF THE HONEYBEE

The tongue of the honeybee is used for lapping up nectar from flowers and is the most highly modified of the mouth parts. What adaptations do you recognize?

and parts of the internal organs are pulled out, and the bee dies. When a bee stings another insect or even another bee, the sting is not lost.

Sometimes small swarms are attacked by bees from other colonies. It is a pitched battle until the "robber bees" are beaten

back or the defenders are themselves killed. The sting is used in these battles.

Bees are instinctively sanitary. If a large bumblebee enters the hive, the honeybees kill the intruder and since he is too large to be taken out, embalm him by injecting the sting repeatedly into his body. The purpose of this operation is to prevent putrefaction of the bumblebee and make him harmless to the colony. Sometimes they cover the body of a small, dead animal with a case made of propolis (prōp'ō-līs), a substance the bees gather from certain buds. This serves to protect the colony from the effects of the decomposition of the body.



FIGURE 85. DOUBLE SWARM OF
HONEYBEES

At irregular intervals during the early spring and summer, bees have the peculiar habit of *swarming* (Figure 85). Several reasons for swarming are given by beekeepers, but no one pretends that he really knows the cause. It is perhaps a sort of revolt of the bees against their domestication. Two other common reasons given to explain swarming are the lack of room for the growing colony and lack of food.

When bees swarm, they usually alight on the limb of a tree and form a dense cluster. Here they hang from fifteen minutes to an hour before leaving for the woods. In a few cases bees have remained in this "cluster" state overnight, but usually they are

lost unless they are collected within three hours. The swarm consists of a large number of adult bees, — workers, drones, and usually only a single queen.

Various devices against swarming have been invented, but the most effective is to clip the wings of the queen in order that she may be kept at home, for the other bees usually follow her. This is done after the queen has taken her “wedding-flight.” The bees that then swarm soon come back. Having found the queen and plenty of room in a new hive, the colony is usually content to remain. Bees that have been raised for many generations in man-made hives sometimes leave the hives suddenly and seek out a hollow tree in the forests in which to live.

The length of the bee's life varies. The drones are usually killed at the end of their first season. Queens live for five or six or even ten years. Workers live three or four weeks in the working season and several months in the fall or winter.

The honey and wax produced annually in the United States are valued at \$25,000,000.

79. Adaptation Illustrated in the Honeybee. — The honeybee offers a fine example of adaptation. The tongue is adapted to getting nectar from certain flowers like apple blossoms, lindens, white clover, and sweet clover. It is too short to get nectar from red clover blossoms. The mandibles are adapted to gathering propolis from buds, also for kneading the wax and for polishing surfaces. The wings are adaptations for the particular life of the

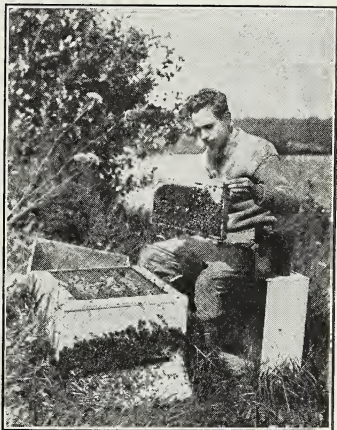


FIGURE 86. YOUNG BEEKEEPER AND FRAME OF BEES

One who knows how can handle frames of bees without being stung.

honeybee. In the first place they are small and are not likely to be injured when the bees are packed closely together as in swarm clusters. Then, to compensate for the small size, the wings are provided with muscles that vibrate them with a rapidity as great as 440 times a second, sufficient to carry the bees through the air with a load of nectar and pollen.

The rear pair of legs is adapted not for jumping, as in a grasshopper, but for carrying loads of pollen and propolis. These legs are flat and thin and provided with bristles to keep the load from sliding off.

80. Ants and Their Social Organization. — Many interesting facts about the honeybees are known because they are so valuable to man, but less attention has been paid to ants, although these seem to be even more wonderful insects.

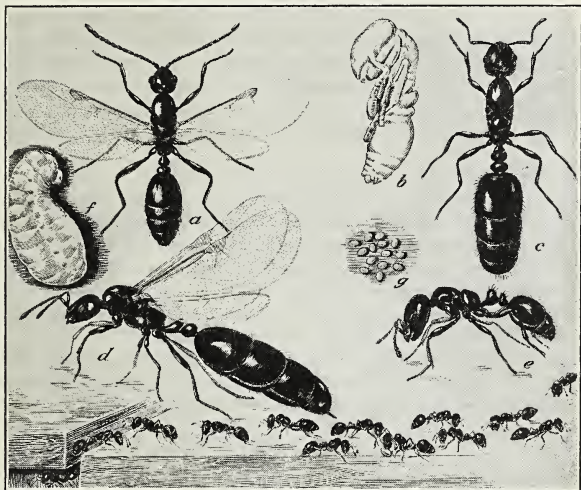
They live in large families with many workers, and a number of queens and males. Some have, in addition, soldiers with strong mouth parts (mandibles) to do the fighting for the colony.

Behavior. — Socially ants perhaps act more like human beings than any other animal. Here are some of the things they do.

1. They build beaten roads with tunnels under brushpiles.
2. They keep plant lice for the sweet fluid they exude; this suggests the keeping of cattle by man.
3. They carry these plant lice into their tunnels and care for them over the winter season. In the spring they carry them out and place them on food-plants.
4. If a nest is attacked by enemies, the soldiers rush around and stroke the workers with their antennæ. This seems to inform them of the attack and they hurry to the rescue.
5. They wrestle and play and sometimes carry one another around. Their activity looks like a football game.
6. They have battles with other colonies. This activity unfortunately also reminds us of man. Before a battle starts they send out scouts and await their return before beginning the battle.
7. When one colony subdues another in battle, the victors take home the larvæ and pupæ of the vanquished and bring them up to be slaves. The slaves seem to be loyal to their con-

querors and to take great interest in the welfare of the victorious colony.

8. Among certain kinds of ants the slaveholders have depended so long on the slaves that they are unable to build nests or even feed themselves. If the slaves are taken away, the slaveholders



United States Bureau of Entomology

FIGURE 87. LIFE HISTORY OF THE LITTLE BLACK ANT

a, male; *b*, pupa; *c*, female; *d*, female with wings; *e*, worker; *f*, larva; *g*, eggs.

A group of workers is shown on the march below.

starve. The slaveholders are able to fight, however, to get more slaves.

Life History. — In most ant colonies there are several queens. Unlike the honeybees, several queens live in harmony in an ant colony. The ant eggs are so small that they are scarcely visible to the unaided eye. The legless larvæ hatch in a few days, being full grown in about two weeks. Pupation lasts about two weeks. The cocoons are the white objects which are commonly called

“ant-eggs.” The adults guard these cocoons which contain the pupæ, carrying them away to places of safety when the colony is disturbed. Sometimes the adult workers remove them to warmer quarters.

The males and females have wings, but the workers are wingless.

SUMMARY

In this chapter you have read how men and women have increased our knowledge of insects by telling in an interesting way what they have observed. You have learned that, though only the specialist can hope to know all of the insects in a given group, every one can derive pleasure from knowing about the commoner ones, among which are monarch butterflies, bees, and ants.

The life history of the monarch butterfly gives us a good illustration of complete metamorphosis. The chief enemies of this butterfly, as of most insects, are the parasites and birds which prey upon them.

Of all insects the bees are the most valuable to man. They live in colonies where the queen alone lays the eggs from which new bees are hatched. Fertilized eggs can result in queens or workers according to the food the workers give them. When a colony becomes crowded, bees usually swarm. They are remarkably well adapted for making honey.

Ants are more like people in their social behavior than any other animals. They build roads, keep other insects for food, have soldiers and slaves, make war on each other, and sometimes even seem to play games.

QUESTIONS

What are some of the most harmful moths? some of the most beautiful? Tell the life history of the monarch butterfly. What does it illustrate? What are two of the chief enemies of moths? What three forms of honeybees are there? How does each come into being? Give the life history of a bee from egg to fully developed worker. Why do bees swarm? How is a swarm handled by the beekeeper? What adaptations has the bee? In what different ways do ants act like human beings? Do they have queens? workers? Tell the life history of the ant.

SPECIAL TOPICS FOR DISCUSSION

1. Do honeybees thrive in your neighborhood?
2. What plants are necessary for them?
3. What diseases are fatal to the bees in a hive?
4. Would you like to have your life arranged like that in a hive of bees or an ant colony?

REFERENCES

- Langstroth, *Hive and Honey Bee*, American Bee Journal
Lutz, *Fieldbook of Insects*, G. P. Putnam's Sons
Matheson, R., *Handbook of Mosquitoes of North America*, Thomas Publishing Company
Osborne, *Economic Zoölogy*, Chapter XII, The Macmillan Company
Phillips, *Bee Keeping*, The Macmillan Company
Root, A. B. C. of *Bee Culture*, The A. L. Root Company
Root, A. B. C. and X. Y. Z. of *Bee Culture*, A. L. Root Company
Wheeler, *Ants, Their Structure, Development, and Behavior*, Columbia University Press

CHAPTER IX

CRAYFISH

*"Will you walk a little faster?" said a whiting to a snail,
"There's a porpoise close behind us, and he's treading on my tail!
See how eagerly the lobsters and the turtles all advance:
They are waiting on the shingle — will you come and join the dance?"*

—LEWIS CARROLL

81. The Crustacean Group. — The *crustaceans* (krūs-tā'shānz) take their name from their hard outer covering. That they are closely related to the insects is most easily seen in the external skeleton and the hinge-joints in the legs, which insects also have. Crayfish, lobsters, crabs, and shrimps are familiar crustaceans.

Insects, crustaceans, and all such animals are called *invertebrates* since they have no backbone.

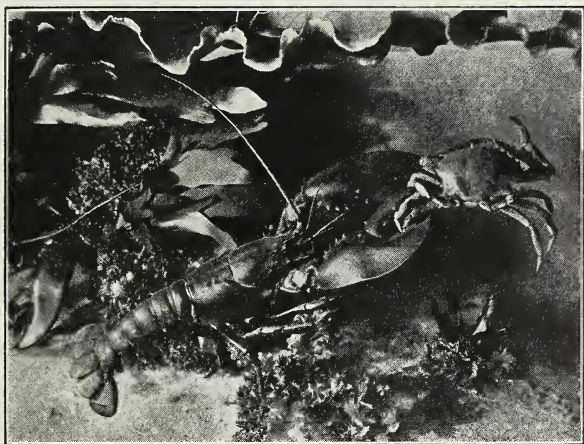
The body consists of segments, each of which usually has a pair of jointed appendages. The appendages are variously modified; some are used in swimming, some in securing food, and others in walking. On the walking legs are located most of the gills that aid in respiration. The others are on the thorax.

The jointed appendage is the chief characteristic of the group to which crustaceans belong. For this reason this larger group, to which spiders and other forms belong, is given the technical name *Arthropoda* (är-thröp'ō-dā).

82. Crayfish. — Either the crayfish or the lobster will serve as an example of the crustacean group. They are so similar that a description of either will indicate the chief characteristics of both animals.

Covering the body is a hard outside skeleton, the *exoskeleton*. In reptiles, fishes, and mammals the skeleton is inside the body with the flesh enclosing it; it is customary to refer to such a skeleton as an *endoskeleton*.

The lime which composes the skeleton is furnished by the food the crayfish eats. As this substance is necessary to its growth, the crayfish lives only in streams where the food contains lime. The exoskeleton protects the crayfish against the animals that prey upon it, and serves for the attachment of muscles as all skeletons do. Its color also helps to protect it because this color usually resembles that of its natural surroundings.



American Museum of Natural History

FIGURE 88. LOBSTER CAPTURING A LADY CRAB

This is a case where victory belongs to the stronger. After crushing the shell of the crab, the lobster tears out its muscles with the smaller pincers on the walking feet and with the mouth parts. The plants shown in this picture are seaweeds that belong to the general family of the algæ.

The crayfish is divided into two regions, the *head-thorax* region and the *abdomen*. The segments of the abdomen are clearly defined, but those of the head-thorax, technically termed the *cephalothorax*, are so fused that they are difficult to make out.

83. Molting. — An interesting thing about the crayfish is that it can shed the outside skeleton. As this exoskeleton is rigid and non-elastic, the crayfish must get rid of it occasionally

in order to grow. Molting is a serious and dangerous operation as it is followed by a period when the crayfish is without means of offense or defense. The animal usually hides until a new exoskeleton is partially formed. In the molting process the covering of the eyes and part of the lining of the digestive tract, as well as

the whole exoskeleton, are shed. The crayfish molts every year of its life and several times during the first year (Figure 89).

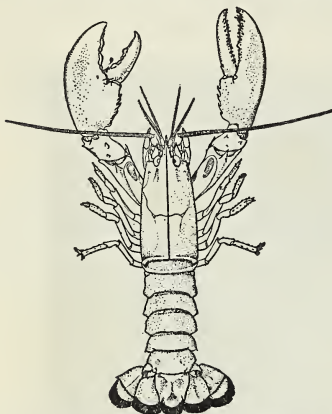


FIGURE 89. THE MOLTED EXOSKELETON OF THE LOESTER

Can you tell how many walking legs there are from this diagram?

form a tail fin (*uropod*, Figure 90). This flattened foot is an adaptation that helps the crayfish to swim backwards.

On the thorax region, the appendages have become large, many-jointed structures strong enough to support the body in walking. (See walking leg, Figure 90.) The first appendage is much larger than any of the others and terminates in a strong pincer (*chela*, Figure 90). The chela is used in fighting, in defense, and in capturing food. On the joints of the walking legs nearest the body are gills that absorb oxygen from the water.

Just in front of the walking legs are located six pairs of appendages that assist in bringing food to the mouth after it has been

84. Appendages of the Crayfish. — Nineteen pairs of appendages, attached to the lower or ventral surface of the body, are used for swimming, walking, protection, capturing prey, and crushing food, and as special sense organs.

The appendages on the abdomen of the crayfish are simple, two-parted feet, called *swimmerets* (Figure 90). The last abdominal segment and the appendages on the one next to the last are broad and

crushed and torn to pieces. There are three pairs of *maxillipeds*, two pairs of *maxillæ*, and one pair of *mandibles* (Figure 90).

The mandible is short and hard and has a broad surface on the end. When the two mandibles come together their action is mainly to crush food, but this broad surface is also rough so that they have a grinding action.

The two pairs of appendages, *maxillæ*, just back of the mandibles are very thin, almost leaf-like, and covered with sensory hairs. These hairs are supplied with nerves and are classified as taste and touch hairs. The second maxilla supports a special fold, scoop-shaped, which extends into the gill chamber. Its function is to help in respiratory movements by keeping the water circulating in the gill chamber. The water is drawn in from the back edge of the gill chamber and passes out near the mouth. We may show this by placing a few drops of red ink at the back edge of the gill chamber of a live crayfish, being sure to have the water cover its back.

The three remaining pairs (maxillipeds, Figure 90) are similar to the abdominal appendages with the parts marked "en" and "ex" much enlarged.

The crayfish has two pairs of antennæ that are used for feeling and possibly tasting. Students of the sense organs in the crayfish and similar animals doubt very much if a crayfish really

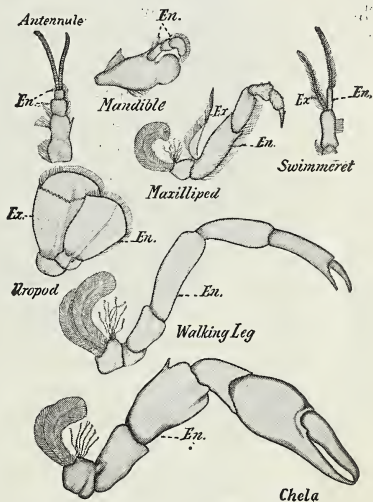


FIGURE 90. SOME OF THE APPENDAGES OF THE CRAYFISH

"tastes" when a drop of meat juice is placed in the water near the mouth parts or an antenna, although the crayfish begins to move the mouth parts as it does when eating.

In the joint of each of the small antennæ nearest the body is a sac covered with a plate, the edge of which is furnished with hairs. The sac communicates with the water. It is the balancing organ. The crayfish is unable to swim naturally when the so-called "ears" are removed.

In Figure 90 the parts of the appendages are marked "en" and "ex" to indicate which becomes enlarged or reduced in comparison with the other. There is no better illustration in zoölogy of the extent of adaptation in the same structure than that shown in the appendages of the crayfish.

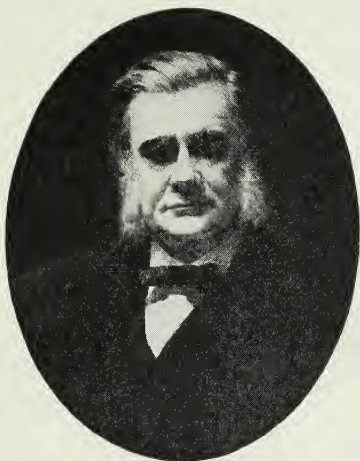
85. Eyes. — The eyes are on the ends of a pair of short, movable stalks. The eye of the crayfish is compound, but it is hardly correct to say that it represents 2500 simple eyes fused into one. But, so far as its action is concerned, this is true, for each lens, or *facet*, "sees" only the object directly before it. Thus, the crayfish does not have a continuous complete picture of an object as we do, but numerous partial and incomplete views that resemble a mosaic floor. Such vision is therefore termed *mosaic vision*.

LABORATORY STUDY ON THE APPENDAGES

Examine more fully than in the above and report the work of each pair of appendages. Compare one of the abdominal appendages with those used in walking and feeling. What is the work of the large pincers? How many fin-like appendages are found in the mouth region? Notice that one of the mouth appendages has a flat part that extends in front of the gills. This part of the appendage is called the gill scoop or bailer. Describe how the appendages show at least three useful adaptations in the life of the crayfish.

86. Life Processes of the Crayfish. — The details of the life processes of the crayfish are very interesting.

Food-Getting Activities. — The crayfish feeds on tiny plants and animals, both living and dead. One of the simple water plants, *Chara* (kā'rā), furnishes the crayfish with lime for its



THOMAS HENRY HUXLEY (1825-1895) was one of the greatest of the English scientists and was the father of the modern method of studying biology. Up to 1850 information about plants and animals was imparted only by lectures. Huxley found that the science of his day contained many errors which were due to lack of first-hand information on the part of the writers. He corrected many of these errors by personal study of plants and animals, and devoted years to developing methods of laboratory study. His directions for studying the crayfish were probably the first laboratory outlines used by students of biology.

skeletons. Shells of snails and their own shed skins also help to supply lime. Crayfish seize food with their pincers and move it towards the mouth. Small food particles are also carried towards the mouth by currents of water produced by the movement of the mouth parts and the abdominal appendages. Particles of food are torn loose by the teeth or mandibles.

Digestive System.—The mouth of the crayfish is just back of the mandibles, and connects with the stomach by a short *esophagus*. The front part of the stomach possesses a grinding structure known as the *gastric mill*, which shreds and crushes the food

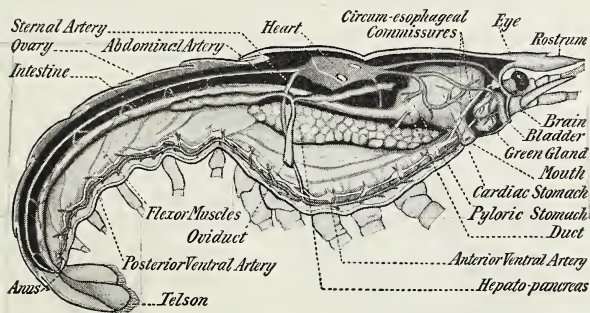


FIGURE 91. ARRANGEMENT OF THE ORGANS IN A CRAYFISH

and makes it ready for digestion in the back part. The *liver*, or digestive gland, pours a fluid into the stomach, which prepares the food for absorption by the walls of the stomach and intestine. The *intestine* begins at the back end of the stomach and extends to the last segment.

✓*Respiration.* — Crayfish obtain oxygen from the water by means of gills. The gills are well covered by the overhanging skeleton, a protecting *carapace*, but are really outside the body. Most of the gills are plume-like in shape and are attached to the appendages, but some of them are attached to the thorax. Water is made to circulate through the gill chamber by means of the gill scoop or bailer.

✓*Excretion.* — The organs for excretion of waste are the *green glands* found at the base of the antennæ. Blood going to these glands loses some of the waste which it has gained in its course through the body. These green glands purify the blood of the crayfish in much the same way as do the kidneys of the higher animals.

✓*Circulatory System.* — The crayfish has a well-developed heart from which extend several arteries which carry blood to the various parts of the body. The blood returns to the heart through veins and through several irregular ducts called *sinuses* (sī'nūs-ěz). As the blood flows through the body, it loses oxygen and receives carbon dioxide. Fresh oxygen is absorbed by means of the gills, which, at the same time, pass off carbon dioxide from the blood into the water.

✓*The Nervous System.* — In the crayfish this is made up of a *brain*, *ventral nerve chain*, and many *nerves*. The special senses are well developed.

87. *Life History.* — The males may be distinguished from the females by the larger tubular appendages on the first and second

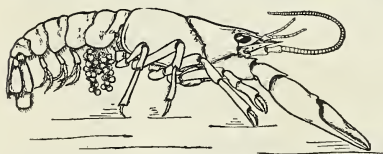


FIGURE 92. CRAYFISH WITH EGGS

The eggs are attached to the swimmerets. What advantages are there in this?

segments of the abdomen. The eggs of the female become glued to the hairs of the swimmerets, where the young crayfish remain for about a fortnight after hatching, grasping the hairs with their pincers. During this time they feed on the yolk that was in the egg. By the end of the fortnight they begin to look like their parents.

The crayfish breeds annually, and those that hatch from eggs laid in the spring may, in turn, lay eggs the following spring.

It is an interesting fact that if one or more appendages are lost in the process of molting, these lost parts grow on again. This is known as *regeneration*.

LABORATORY STUDY

Place several crayfish in jars or aquaria and observe their behavior. Copy the following table and fill it in. Do not mark your book.

DO THEY MOVE THE ANTENNÆ?	DO THEY WALK FORWARD?	DO THEY WALK BACKWARD?	DO THEY USE TAIL FINS?	DO THEY MOVE EYES?	WHAT ORGANS MAKE A CUR- RENT IN WATER?

88. Value to Man. — Crayfish, shrimps, lobsters, and crabs are very important economically on account of their food value. The trade in these animals amounts to millions of dollars each year. In order that these important food animals may not become exterminated by careless and excessive fishing, the state and national governments have attempted to control the numbers taken. Crayfish are sometimes harmful since, by burrowing, they may cause serious damage to dams and levees.

As a source of food the American lobster is widely used, as its body contains a large supply of delicious meat. It is in such great demand that the states of the northern Atlantic coast have made a size regulation to prevent small lobsters from being taken.

In order to keep up the supply of lobsters, state and national governments have established hatcheries where the eggs are hatched artificially. During this process the eggs are protected from the animals that naturally feed on them. After the young lobsters are hatched, they are placed in the ocean.

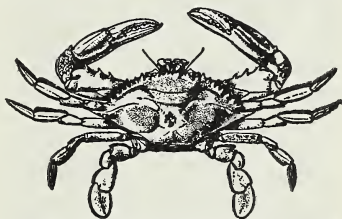


FIGURE 93. SOFT-SHELLED CRAB USED FOR FOOD

Shrimps and the soft-shelled crab (Figure 93) are also food for man, while the minute crustaceans are an important food for fish (Figures 94 and 114).

89. Other Crustaceans. — Crustaceans of less economic importance than shrimps, crabs, and lobsters are the barnacles which cling to rocks, wharves, and ships; the hermit crabs that live in the shells of mollusks; and the smaller fresh-water crustaceans which are barely visible to the eye.

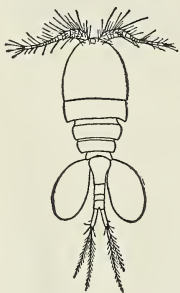


FIGURE 94. CYCLOPS, A SIMPLE AQUATIC CRUSTACEAN EATEN BY FISH

With what crustaceans are you familiar? Describe the crayfish. How many parts has its body? What kind of appendages does it have? How does it take food? respire? excrete? Describe its circulatory and nervous systems. Where do the eggs remain until hatched? What is molting? How are crabs and lobsters important to man?

SUMMARY

Each student should bring in a summary of this chapter and the best one should be read to the class.

QUESTIONS

SPECIAL TOPICS FOR DISCUSSION

1. How does the crayfish compare with the grasshopper?
2. Why do we say that the insect is the higher?
3. What are the different things that a crayfish can do with its legs? How does this compare with what the grasshopper can do?
4. What animals feed on crustaceans?

REFERENCES

- Calkins, *Biology*, Chapter VII, Henry Holt and Company
 Cockerell, *Zoölogy*, Chapter XXXV, World Book Company
 Herrick (United States Fisheries Bulletin, Volume XV, 1895), *American Lobster, Study of Its Habits and Development*
 Jordan, Kellogg, and Heath, *Animal Studies*, Chapter IX, D. Appleton and Company
 Pearse, *General Zoölogy*, Chapter XI, Henry Holt and Company
 Smallwood, *Textbook of Biology*, Chapter XVII, The Macmillan Company

CHAPTER X

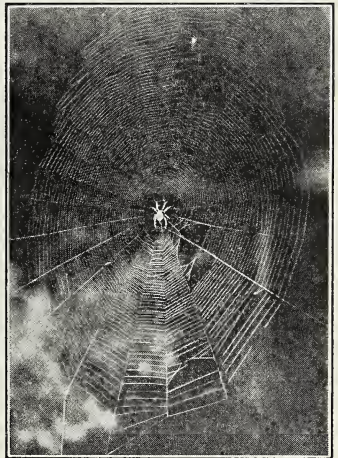
SOME OTHER INTERESTING INVERTEBRATES

*Much like a subtle spider, which doth sit
In middle of her web, which spreadeth wide:
If aught do touch the utmost thread of it,
She feels it instantly on every side.*

—SIR JOHN DAVIES

90. Introduction. — Insects are so numerous and touch our lives in so many ways that we often do not take time to become acquainted with other interesting invertebrates. We should, however, know of their existence, and any group of invertebrates might well be taken up as a special hobby: worms and spiders by those who live inland and clams and starfishes by those who have the seashore for their playground. The books of reference at the close of this chapter can be read in addition to your regular work. These books will guide you in your study of any group which you may select and will furnish you with many interesting facts.

The records of the rocks indicate that there have been starfishes and clams for millions of years, and their habits throughout this long period have remained



Ewing Galloway

FIGURE 95. THE WEB OF A SPIDER

How is this web made?

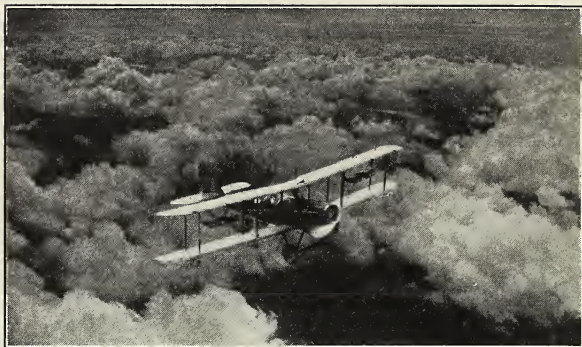


FIGURE 96. AN AIRPLANE, EQUIPPED WITH INSECT TRAPS

Above: The plane flying through the air catching insects.

Below: After the flight, the insects are removed from the screens of the insect traps.

similar to what they are today. Brief mention is made of only a few of the interesting invertebrates. In chapter XXIV further consideration is given to the invertebrates that are simpler in structure than those discussed here.

91. Arachnids. — Spiders, scorpions, ticks, and mites make up a class of Arthropods which are called arachnids. The jointed appendages, external skeleton, and the body regions of these animals should reveal to you at a glance that they are similar to the crayfish.

Spiders are the best known of the arachnids and most of them are harmless. Some spin beautifully regular webs in the grass, in the shrubbery, and on the porches of our houses. In the fall the young of some kinds of spiders climb fences, weeds, and even telephone poles and spin long threads of silk on which they sail away. They have been caught by traps attached to government airplanes at heights of 10,000



FIGURE 97. A BALLOON SPIDER

This spider climbs to the top of some fairly high object and lets out many filmy strands of silk. These float away with the upward currents of air and lift the spider with them. Many spiders are carried hundreds of miles in this way.

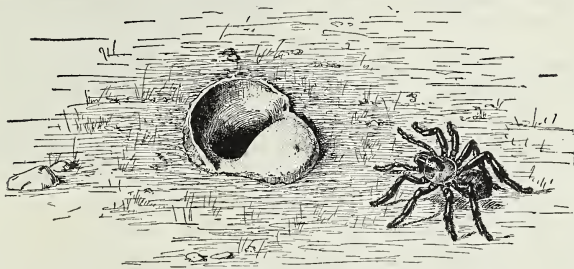


FIGURE 98. THE TRAPDOOR SPIDER

This spider waits at the door of the trap for the unlucky victim, seldom leaving his home.

feet. Air currents may distribute them over vast areas in a few days.

In the southeastern part of the United States trapdoor spiders are found. They dig a hole in the ground, fasten a hinged lip to fit, and cleverly open and shut this like a door, even spinning a silk handle on the inside to hold it shut against an enemy.



U. S. Department of Agriculture

FIGURE 99. A SCORPION

How does the scorpion differ from a crayfish?

Spiders catch honeybees that are useful and flies that are harmful, but we study them because they are interesting rather than economically important. The harvest-man (daddy-long-legs) is common and harmless and belongs to the spider group.

Scorpions live in tropical and subtropical regions. They have a pair of legs modified to form pincers like the lobster, and eight walking legs like spiders. At the tip of the tail, there is a sting which is fatal to their prey, which consists chiefly of insects and spiders. Although painful, the sting usually does not injure human beings.

Mites and ticks are the smallest of the arachnids. The "red" spider that injures apple leaves and fruit is really a mite. Relatives of these red spiders are the "chiggers" of the South that annoy human beings. Ticks are harmful not only because they feed on various domestic animals but because they transfer disease from one animal to another as well as to man.

92. Myriapods. — Another group of the Arthropods is the myriapods, which include animals of many legs such as the centipedes and "thousand-legged worms." Centipedes are provided with poison glands, which make their bite fatal to some small animals and painful to man. The "thousand-legged worm,"

or millipede, is harmless. Catch a centipede and observe carefully how it walks and you will then enjoy the following ditty :

“The centipede was happy — quite !

Until the toad in fun
Said, ‘Pray which leg moves after which?’

This raised her doubts to such a pitch,

She fell exhausted in the ditch,
Not knowing how to run.”

93. Echinoderms. — In this group are starfish, sea urchins, sea-cucumbers, and crinoids. All forms are restricted to living in the ocean. They are quite different from other animals in the arrangement of their organs and in the possession of some that are not found elsewhere. For this reason there is much difference of opinion as to where they should be placed in any scheme of



American Museum of Natural History

FIGURE 100. CENTIPEDES



FIGURE 101. A STARFISH

How do you explain the short arm?

classification. Their peculiar arrangement of organs was first brought about millions of years ago, and it has remained fairly constant until the present. They are characterized by a starlike radial arrangement of the body which is in marked contrast to the paired or bilateral form of a crayfish or a vertebrate. They have tube-feet for holding on to surfaces and these

tube-feet are manipulated by a special organ system, the water vascular. They are very destructive to oysters and clams. Try to find out how they are able to kill such animals.

An interesting characteristic of the starfish is its power of regeneration, that is, to grow new arms. Sometimes oyster fishermen have broken the starfish over the edge of the boat and thrown the broken parts back into the water, but instead of killing

the starfish, they have made it possible for two to develop.

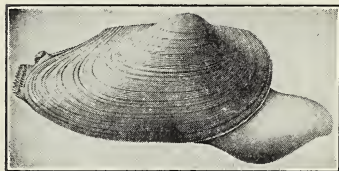


FIGURE 102. FRESH-WATER CLAM SHOWING FOOT

94. Mollusks. — Mollusks have had a close relation to man from his earliest appearance. Huge piles of clam and oyster shells remain as records of his feast celebrations. From ancient times

until today, when the oyster industry is valued at \$15,000,000 and the clam industry at \$1,000,000 a year, these animals have held an important place in the economic life of man.

Mollusks differ from the crustaceans in having an unsegmented body. It is usually covered by an exoskeleton, consisting of a single piece in snails, and two valves in clams. When the clam moves naturally, the hinge between the two valves is uppermost while the opening between the valves allows the foot to be extended into the mud (Figure 102). The foot is a thick muscular mass, not at all foot-like in appearance, but it enables the clam to move slowly at an even rate.

Not only are clams valuable as food, but the soft parts are used as fertilizer and the shells are manufactured into buttons.

A few years ago this industry nearly failed because the life history of fresh-water clams was not understood. Two well-known biologists were employed by the United States government to investigate the breeding habits, methods of hatching, and conditions of growth. These men found that young clams swim about by opening and closing their tiny valves. (See Figure 103.) The young clams are taken into the mouth of



FIGURE 103. EMBRYO CLAM

It passes part of its life attached to the gills of a fish.

fishes and passed out with the water through the gills. Some of them hook into the gills. Finally they loosen their hold and settle down for their later development. As soon as these facts in the life history of clams were well understood, it was possible to formulate regulations governing the time when clams and the kinds of fish best suited to their development could be taken.



FIGURE 104. COMMON FRESH-WATER FLATWORM

95. Flatworms. — This group of invertebrates includes a few inconspicuous forms occurring in fresh-water ponds and streams and a considerable number that live as parasites within the bodies of many animals, including man.

The common planarian worm (Figure 104) is a flat, worm-like creature about an inch long that feeds on decayed organic matter and may well be termed a scavenger. The head contains eyes and a small brain but no mouth. The mouth is at the end of a long tube that sticks out of the middle of the body. There are no organs for circulation, and respiration takes place only through the skin, but we do find that the digestive tube branches extensively and thus carries food to all parts of the body. The free-living planarian worm is one of the simplest members of this group.

Another member is the tapeworm, of which there are many different kinds, but in their structure and habits tapeworms are much alike. They have long bodies, some of which are reported to be eighty feet long. There are suckers and hooks on their heads, which are used to cling to the wall of the intestine. They have no digestive system, but are able to absorb their needed amount of food

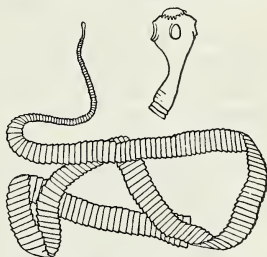


FIGURE 105. ADULT TAPEWORM AND THE ENLARGED HEAD END

because they are constantly bathed in it in the intestine of some other animal.

The body of the tapeworm consists of a chain of segment-like parts that are adapted for purposes of reproduction. The number of these segments may be two hundred or more. The segments at the free end of the body become ripe and drop off.



*American Museum of
Natural History*

FIGURE 106. YOUNG
TAPEWORM

The word *ripe* is used here to mean that the eggs in the segment have matured and are ready to develop into more tapeworms. A single adult tapeworm may discharge millions of eggs. Each of these eggs, which have already begun to develop before they are discharged, is surrounded by a tough sac. The young embryo is unable to develop further unless eaten by another animal. The young tapeworms in their sacs do not search for the animal that is necessary for their further growth and, unless accidentally eaten, they die. As soon as a young tapeworm enters the intestinal tract of a second animal, the tough sac is lost and the worm begins

to migrate into the tissues. In the tissues it passes through more changes in growth, but is small and unlike the parent. Here it must remain until eaten by an animal similar to the one from which the eggs escaped, after which it will become a mature tapeworm.

96. Roundworms. — The roundworms are as small and inconspicuous as the flatworms but much more numerous. One of the smallest is the form occurring in vinegar and so termed the "vinegar eel." By far the larger number of them live in the soil, the water, or the bodies of plants and animals. These are the animals that legend has it come from placing a horsehair in a spring of water. Figure 107 shows one of these worms in the body of a grasshopper, where it lives as a parasite during one of the stages in its regular life history. After it matures, it makes its



CHARLES WARDELL STILES (1867-) was born at Spring Valley, New York. He was zoölogist in the Bureau of Animal Industry of the United States Department of Agriculture from 1891 to 1902, and has been zoölogist in the United States Public Health Service and assistant surgeon general since 1902. Dr. Stiles has been given honorary degrees by several American universities and is a member of international commissions.

The symptoms of hookworm disease were clearly described by the early Egyptians. For centuries the disease was recognized from its most marked symptom of anemia. In the United States, a few years ago, it existed to an alarming degree. Dr. Stiles estimated from his researches that more than 2,000,000 people were infected with hookworm in the area east of the Mississippi from the Potomac River to the Gulf of Mexico.

In the eastern hemisphere two distinct parasitic worms are the cause of the disease ; in America a third species is found.

Dr. Stiles has made important discoveries about the cause and prevention of the hookworm disease in America. His services to human betterment in this field alone entitle him to be ranked as one of America's great benefactors.

way out of the body of the grasshopper into a stream and the ignorant believe that a horsehair has become alive.

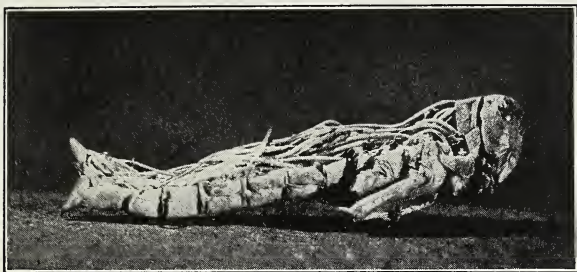


FIGURE 107. ROUNDWORM IN THE BODY OF A GRASSHOPPER

Another roundworm lives in the intestines of mammals and from there migrates into the muscles. In the muscles it becomes encysted and here it remains until the flesh is eaten by some other mammal. When pork, infected with this parasitic roundworm, is insufficiently cooked and eaten by man, the cysts are dissolved by the digestive enzymes and the worms are freed.

The worms then develop eggs and sperms which, after uniting, mature into young worms and migrate through the intestinal wall into the muscles. The activity of the worms at this stage causes a serious inflammation of the muscles of man and a disease named after the worm, *trichinosis* (trīk'ī-nō'sis), follows.

The hookworm is another one of the roundworms and causes the hookworm disease. This disease belts the earth in a zone which extends thirty-three degrees on each side of the equator.

97. Segmented Worms. — The third and highest group of worms includes earthworms, sandworms, leeches, and many

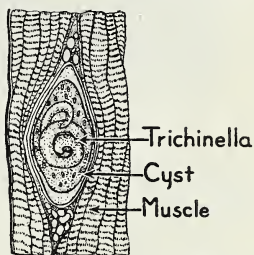
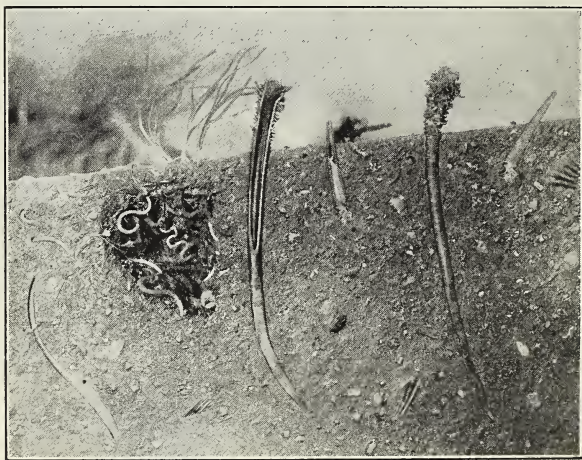


FIGURE 108. A DANGEROUS ROUNDWORM

How does it get into our bodies?

others. The arrangement of the organs in an earthworm indicates that they are well defined so that one can refer to the digestive canal, circulatory structures, and a central nervous system. Ring-like grooves divide the body into segments and when the body is opened partitions are seen to correspond to the grooves. Each segment bears appendages and contains a pair of tubes that act as kidneys, a ganglion with nerves, and other organs so that a



American Museum of Natural History

FIGURE 109. SEGMENTED WORMS THAT LIVE IN TUBES

segment in these worms is very different from that found in a tapeworm.

After a rain you may have noticed a large number of earthworms crawling on the sidewalk or pavement, if you live in a small town or in the suburbs of a city. Or if you chance to be so fortunate as to have a garden plot, you may have noticed their openings and castings when you examined the garden in the morning. In either case you have some idea of how numerous earthworms are in fertile soil. Charles Darwin in his book

Vegetable Moulds and Earthworms tells an interesting story of the important part that earthworms play in enriching the soil.

The several groups of invertebrates listed in this chapter have another interest that the practical-minded overlook. Some of them produce eggs so transparent that the changes that take place in them during the early stages of growth can be seen in the living state. The exact nature of fertilization was discovered in this way. That was more than fifty years ago and from that time scientists have studied various members of these invertebrates and have made discoveries that have added greatly to our understanding of the nature of life.

SUMMARY

There is no close relationship in the several kinds of invertebrates included in this section. They are, however, representative of groups of well-known animals that one should know about. Each group would do well for your special leisure hobby.

QUESTIONS

What are mollusks? How many kinds do you know? Of what use are they to man? Which of the myriapods are harmful and which harmless?

SPECIAL TOPIC FOR DISCUSSION

Are spiders beneficial or harmful?

REFERENCES

- Comstock, *Handbook of Nature Study*, Comstock Publishing Company
 Doane, *Common Pests*, Thomas Publishing Company
 Fabre, *Insect Adventures*, Chapters XVIII–XXV, Dodd, Mead Company
 Herrick, *Insects Injurious to the Household and Annoying to Man*, American Book Company
 Rogers, *Shells*, Nature Library
 Scientific Monthly, May, 1931
 Wells, Huxley and Wells, *The Science of Life*, Doubleday, Doran
 Yearbook of Agriculture, 1931, pages 321–323, *Many Insects of High Altitudes*

CHAPTER XI

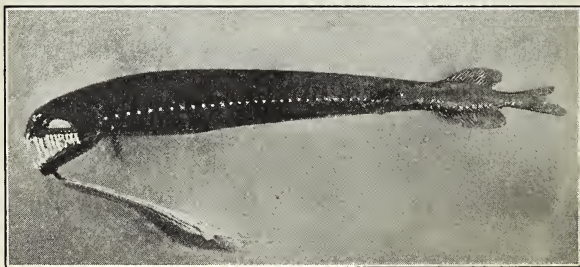
A SIMPLE VERTEBRATE, THE FISH

"Master, I marvel how the fishes live in the sea."

"Why, as men do a-land: the great ones eat up the little ones."

— PERICLES

98. General Characteristics of Vertebrates. — Having studied insects, crustaceans, starfishes, clams, and other invertebrates, we are now to study the *vertebrates*, animals with a backbone, such as fishes, frogs, snakes, birds, and mammals.



American Museum of Natural History

FIGURE 110. MODEL OF A DEEP-SEA FISH TAKEN NORTHWEST OF SUMATRA

It has long, strong teeth. Does this fish live on plants or on animals? The tail is well developed. Do you think that this fish can swim rapidly? Give your reasons. The water is so deep where this fish lives that there is no light from the sun; along its side the fish has light organs. The large fleshy structure hanging from the lower jaw is possibly an organ of touch.

The most important characteristic of vertebrates is the *backbone*. The presence of *gill slits* also characterizes all vertebrates. In the fishes these are external openings on the sides of the neck, which thoroughly expose the gills to the water. Such structures

are of use only to aquatic animals; yet all vertebrates have them at some time in their development.

Most vertebrates have a bony skeleton, and there are usually two pairs of appendages (legs and wings or fins) attached to the body at the shoulder and hip. Special bones join the limbs to the body. The bones in the shoulder are known as the *pectoral* (pěk'tō-rāl) girdle, and those in the hip are termed the *pelvic* (pěl'vīk) girdle. In the snakes, only traces of legs are found.

Another outstanding feature of all vertebrates is the *head* protecting the well-developed nervous system with its large brain. In the head are located also the sense organs, such as eyes and ears, which are better developed than in any of the invertebrates.

Oxygen is obtained by external or internal gills in most aquatic animals and by lungs in all other vertebrates. In many vertebrates the skin is an active agent in the interchange of oxygen and carbon dioxide, particularly in those animals which have a thin, moist skin, as frogs have.

99. Fishes. — There are four large divisions of fishes: (1) the lampreys (lām'prīz), (2) the sharks, (3) the bony fishes, and (4) the small group of fishes with lungs. The bony fishes constitute the most important group in numbers and economic importance. This group includes the salmon (sām'ŭn), trout, bass, whitefish, pike, shad, menhaden (mĕn-hā'd'n), cod, mackerel, and herring. The goldfish, perch, and sunfish (Figure 111) are typical bony fishes but not important.

100. Structure of a Fish. — The external parts of a fish consist of a well-marked *head* attached directly to the trunk; a *trunk region*, the largest part of the body; and a *tail* which is sometimes as long as the trunk.

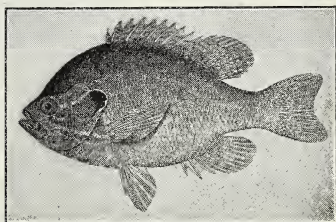


FIGURE 111. SUNFISH, OR PUMPKINSEED
The joy of the small boy fisherman.

In a bony fish the eyes are well developed, the mouth is at the front end of the head, and the jaw bones bear many small, needle-like teeth. The part of the head next to the trunk is protected

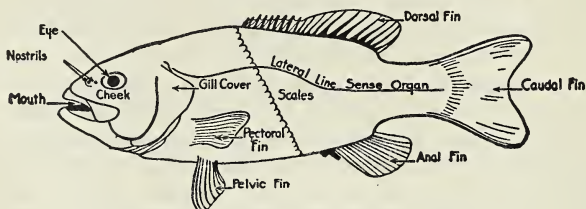


FIGURE 112. EXTERNAL PARTS OF A FISH

by a piece of bone that covers the gills (gill cover or *operculum*, ô-pûr'kû-lûm).

The trunk bears a number of appendages called *fins*. Each fin is composed of several bony fin rays covered by a thin fold of skin. On the shoulder and hip regions of the trunk, the fins occur in pairs and are called the *pectoral* and *pelvic* fins. Several fins, called *median* fins, do not occur in pairs.

The tail region of the fish ends in a large median fin that is used chiefly in locomotion, but the other fins help in balancing, steering, and stopping.



FIGURE 113. TWO TYPES OF FISH SCALES

Scales cover the trunk and tail, each one overlapping the next like the shingles of a house. If you seek to know how old a fish is, simply remove several scales from the side

of the body, place them under a low magnification (even a good hand lens will suffice) and count the main curved lines, for each scale shows the yearly lines of growth. You will find that in some years the growth was more rapid, for the lines are farther apart. The skin is full of mucous glands that keep the fish covered with slime. Both the slime and the scales protect the fish (Figure 113).



DAVID STARR JORDAN (1851–1931) was born in Gainesville, New York. He took his master's degree from Cornell in 1872, his medical degree from Indiana Medical College in 1875, and his doctor's degree from Butler University in 1878. He also received the honorary degree of doctor of laws from four of the leading American universities.

In addition to teaching biology for many years, he wrote numerous technical and popular books on various phases of biology. From 1885 to 1913 he was president first of Indiana University and then of Leland Stanford University. During all this time he continued his scientific studies. He was one of the most eminent authorities on fishes in the United States. Dr. Jordan's life and attainments are striking examples of what an American boy can accomplish by his own efforts and individuality.

LABORATORY STUDY

Study living fish, such as goldfish or perch. Place one or two in an aquarium and observe their behavior. Copy the following table and enter your report. Do not mark your book.

NUMBER OF FINS	NUMBER OF PAIRED FINS	NUMBER OF UNPAIRED FINS	WHICH ARE USED TO			DO THE EYES MOVE?
			ADVANCE?	STOP?	BALANCE?	

Note the shapes and relative sizes of the head, trunk, and tail region. The gills are covered by a bony shield, the operculum. What is its size and how is it attached? Where are the eyes located? Do they move? Can the eyes be closed? How is the body covered? Of what use is this covering to the fish?

101. Locomotion. — The bodies of most fishes (Figures 110 and 111) illustrate an adaptation for swimming. The tapering head offers but little resistance to the water and the general spindle-shape of the whole body enables it to move easily when completely surrounded by water. The paired fins are similarly placed to the paired legs of a frog or dog, but are used mainly for steering. They also act as brakes when the fish wants to stop, the brake being applied by simply straightening out these paired fins at right angles to the body. The median fins on the back and lower surface of the body keep the fish from tipping over and are chiefly for balancing, the paired fins also assisting in this process. The tail with its large terminal fin is often one third of the entire length of the body of rapidly swimming fishes, and is the chief organ of locomotion. Movement is produced by a rapid sidewise motion of the tail.

102. Food-Taking. — The food of fishes consists of insects, worms, crayfish, snails, and other fish. Their teeth serve to seize, tear, and hold food. None of the fish have teeth adapted to chewing food, as is the case among the higher vertebrates like the dog, horse, and man.

Fish can be grouped into those that are almost exclusively fish-eaters such as lake trout, pickerel, and pike, and those that rely chiefly on insects for their food supply. In this latter class, we find bass, sucker, bullhead, perch, and others, although some of these occasionally eat fish. In their diet, fish relish small crustaceans, crayfish, and the minute forms of life that float near the surface of the water.

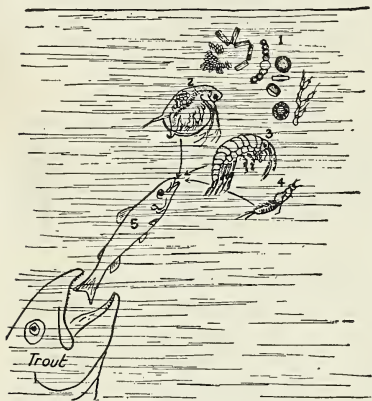


FIGURE 114. FOOD CYCLE IN A POND

The trout feeds on small minnows (5); these eat aquatic crustaceans and insects (2, 3, 4); these eat the minute water plants (1). How do these water plants secure their food?

The young of bass, carp, perch, and a host of minnows live on this food. These minute animals in turn gain their necessary food from the green plants, so there are most interesting biological processes going on in all of our ponds and streams. We are just beginning to understand some of these relations in fresh waters and it will be a long time before man can master the biology of the oceans from which comes our main supply of fish.

Among fish which eat minute animals and plants,

the four pairs of *gill arches* have many sharp-pointed projections on the inside, called *gill rakers*, that act as strainers and gather quantities of this small food as the water passes over the gills (Figure 115). Their development seems to vary in proportion as they are needed for service. Fish that feed on crayfish and on small fish have no use for gill rakers or strainers and accordingly their gill rakers are undeveloped.

103. Digestion. — The food eaten by the fish passes at once into a short esophagus which expands into the thick-walled stomach. Here the various plants and animals that have been

swallowed undergo partial digestion, the remainder of the process being completed in the intestine. The dissolved foods are absorbed through the walls of the stomach and intestine by osmosis and pass into the blood. The main parts of the digestive system and their adaptation to digestion are the same as in all the higher vertebrates.

104. Gills and Respiration. — Have you noticed goldfish constantly opening and closing their mouths? This is how they get oxygen. Water is taken in through the mouth and passes out through two openings, one on each side of the neck. In each opening four or five gills are found. The gills are made up of numerous, small, very short, fleshy threads or *filaments* (Figure 115). Into each filament a blood vessel penetrates and here the blood throws off carbon dioxide and takes oxygen from the water by osmosis just as the blood of the crayfish does. The thin-walled gill filaments are adapted to respiration in the water. The water is drawn into the mouth and forced out over the gills in much the same way as water is pumped from a well. When a fish opens its mouth, the water rushes in. As the mouth is closed, the floor of the mouth and throat is raised slightly, pushing the water against the side of the neck and through the gill opening. The mouth is thus emptied of water, so that when it is opened again, more water flows in.

105. Circulation. — The blood of fishes circulates in well-defined blood vessels, and, pumped by a two-chambered heart, flows from the heart to the gills, where it is purified of carbon dioxide and receives oxygen. It is then carried by means of arteries to other parts of the body, where the oxygen in turn is given

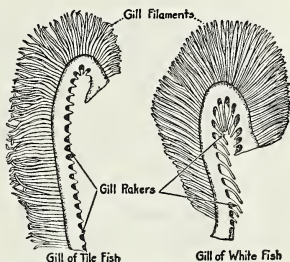


FIGURE 115. GILLS OF FISHES SHOWING DIFFERENT KINDS OF GILL RAKERS

Can you tell anything about the food of these two fishes by their gill rakers?

up and carbon dioxide is received. The blood from the gills and other parts of the body is returned to the heart through veins. Because the temperature of the blood of fishes is the same as that of the surrounding water and changes with the seasons, they are called cold-blooded animals.

106. Excretion. — In addition to oxidation, there are other vital processes taking place in all the cells of the body of the fish. These processes produce waste substances that exist in the form of liquids which are gathered up by the small blood vessels and carried to the kidneys of the fish. Here these liquid wastes are extracted from the blood and are cast off from the body.

107. Nervous System. — The nervous system consists of a spinal cord and a well-developed brain. There is no structure in the nervous system of a crayfish that can be compared to the brain of a fish. Many nerves connect the brain and spinal cord with all parts of the body and these nerves are a part of the nervous system. Associated with better development of the brain are special sense organs.

Special Senses. — The eye is well developed. It is globular and projecting and is believed to be near-sighted. The organs of smell are usually located in the nasal cavity. In the bullhead, organs of taste are found in the feelers, on the head, and even in the skin of the tail, as well as in the mouth cavity. The ear is under the skin, and there is no external opening. As water conducts sound vibrations more readily than air, no special device for gathering sound waves is necessary.

108. Reproduction. — The sexes of fish are distinct. At certain seasons many fish migrate upstream to lay their eggs (to *spawn*). Eggs are laid in large numbers by the females, and in the same locality sperm cells are discharged into the water by the males. The sperms unite with the eggs. The fertilized eggs hatch after from seven to forty days, or later; the time depends on the kind of fish and the temperature of the water. The yolk of the eggs is attached to the young fish for many days after they are able to swim, and supplies all the food they need during this time (Figure 116).

The spawning habits of fish must be understood thoroughly if they are to be raised artificially, as in fish hatcheries. Most states have scientific game laws which protect the fish during

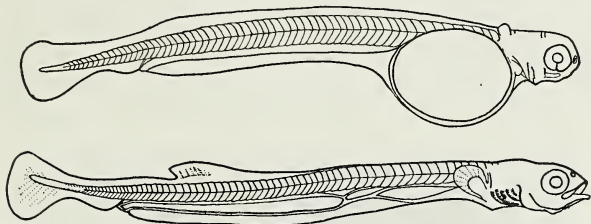


FIGURE 116. YOUNG FISH JUST AFTER HATCHING (*above*) AND SEVENTEEN DAYS LATER (*below*)

The fish at first lives on the yolk mass beneath the neck.

their egg-laying period when they are easily caught and when the destruction of even a few fish means the loss of thousands of eggs.

Spawning habits vary greatly. Some fish, like the salmon, make long journeys from the sea to the head waters of rivers and streams to deposit their eggs. The Columbia River is famous for the number of salmon which spawn there. Other fish, like shad, go up a river only a short distance to lay their eggs. Many shad, for instance, go up the Hudson River in New York State.

109. Care of Young. — A few fish, like the sticklebacks, build nests of sticks and leaves in which the eggs are placed and guarded. Bass and sunfish make a circular depression about a foot in diameter near the shore and lay their eggs on these so-called "beds." The beds are guarded zealously by the males, who drive off or carry away crayfish and small fish which feed

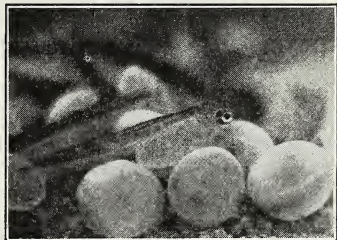


FIGURE 117. BABY TROUT AND TROUT EGGS

upon their eggs. In former times men sought for these beds and by dropping a baited hook caught the bass while it was defending its eggs. Fortunately this practice is now illegal. Generally, adult fish pay no attention to their young and in many cases they devour young of their own kind as quickly as fish of other sorts.

110. Life History of the Eel. — So many stories and myths have been told in connection with the development of this well-known fish of the inland streams and lakes that much effort has

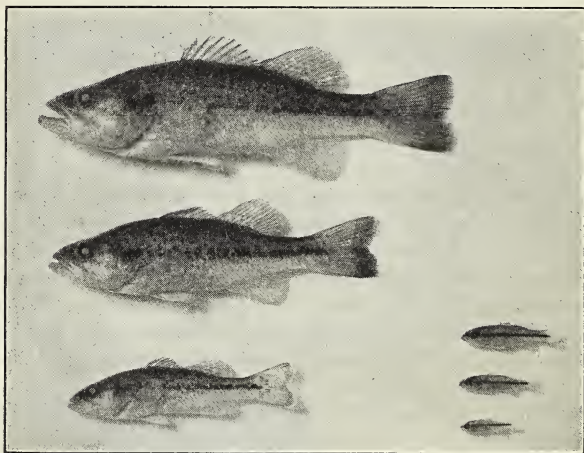


FIGURE 118. GROWTH STAGES IN BASS DURING THE FIRST YEAR
The smallest fish is about $\frac{3}{4}$ inch long. The adult is five inches.

been made to learn the facts. Eels migrate downstream to the ocean in the fall of the year, seeking out mud banks, where the females lay their eggs in great numbers and the sperm cells of the males fertilize them. In some cases the females lay as many as 10,000,000 eggs at one time. After the eggs are laid the adult eels remain in the ocean a few weeks and then die. Young eels and lampreys pass through a larval stage after the eggs hatch.

At the beginning of the second spring the young eels start on their trip back to fresh water. Great numbers of them may be

seen in the spring at the foot of Niagara Falls, where they are blocked by the great cataract. By crawling over stones and along the banks, young eels are able to get above ordinary falls in the streams and rivers.

111. Insect Enemies. — The insects which form the principal diet of many fish are so well known that anglers select special ones for bait. However, not all water insects are eaten by fish. Contrary to the usual order of things, there are insects that kill



FIGURE 119. A SPIDER THAT CAPTURES FISH

young fish. The fish-killing insects spend all of their time in the water except when migrating from pond to pond or during the mating period. They conceal themselves beneath stones or lie partly buried in the mud. From these places of hiding, they dart out and seize their victims with their jaws or claws. The water-tiger, a larva of one of the water beetles, is equipped with curved, sharp, hollow jaws with which it pierces its prey and sucks the juices of the body. The largest and most destructive of these fish-killing insects is a true bug which, like the spider (Figure 119), grasps the fish with its curved forelegs, plunges its large, sharp beak deep into the fish, and then slowly sucks its blood. These



Courtesy Division of Fisheries and Game

FIGURE 120. A CANNERY AND A HATCHERY

Above: A salmon cannery in Alaska.

Below: Where three sets of ponds run into one stream at the Montague Rearing Station. The eggs are hatched in the building at the right and placed in the ponds when old enough.

and other insects feed on the eggs of fish, so that, when hatching fish artificially, man has to protect the eggs and young fish from insects which we used to think were only a source of food to the growing fish.

112. Importance to Man of the Food-Fishes. — The United States, including Alaska, takes from the water about 3,000,000,000 pounds of fish annually, valued at over \$100,000,000. Alaska produces about one fourth of this total. The hatcheries of the United States have an output of 4,500,000,000 eggs, fry (§ 114), and small fish.

113. Need of Fish Protection. — As the human race increases in numbers it requires more and more food. Since most people are fond of fish, these animals are caught in ever-increasing numbers by the men who supply the fish markets.

The fish that are most useful as food are taken by hooks, nets, and seines, under certain restrictions. Those like brook trout, which are caught as much for sport as for food, can be taken only by a hook and line and in certain seasons, the season of the year

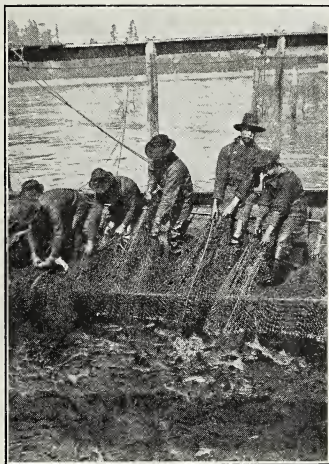


FIGURE 121. SALMON FISHERMEN HAULING IN A NET FULL OF SALMON



FIGURE 122. THE LAKE LAMPREY WHICH KILLS LARGE NUMBERS OF GAME FISH

depending upon the time of spawning. The brook trout spawns in August and September, while the rainbow trout does not spawn until February or March.

During the past twenty-five years the breeding habits of fish have been thoroughly studied, and the breeding periods have been the basis of all the protective laws. This is the reason why the closed season for one kind of fish is different from that for another.

114. Fish Hatcheries. — In the natural state, many eggs are laid that never hatch because the sperm cells do not come in contact with them; and of the fishes that are hatched only a small proportion reaches maturity. As it is a matter of great economic importance that fish be saved from extermination,



FIGURE 123. COMMON DOGFISH

This small shark feeds on our food fish.

the governments of the world have established hatcheries where fish are raised in great numbers to be distributed to suitable waters.

In these hatcheries the eggs are taken from the female and placed in a jar, and the mass of minute sperm cells or *milt* is taken from the male and poured over the eggs, so that practically all the latter hatch. Then if the developing eggs are protected and the young fish are given sufficient and proper food, nearly all these eggs develop into active fish. When they are able to take care of themselves, these *fry*, as the young hatchery fish are called, are taken to natural feeding grounds.

It is not sufficient simply to know how to hatch fish and feed the fry; one must have an accurate knowledge of the kinds of food available for the fry when they are placed in a stream, pond, or lake. This means that one must know a great deal about the

general life of the waters that are to be stocked. What are the enemies of the fry? What plants supply the most food for the young fish? Is the water polluted by the wastes of some manufacturing process? These are some of the more important problems that must be solved before it is wise to set the fry free.

115. Humane Methods of Catching Fish. — Every one who has ever been fishing knows that many of the fish caught are too small for use. The protective fish regulations make it illegal to keep them. They should be put back into the water. What is the proper way to remove them from the hook? When taking any undersized fish off the hook, always wet your hand before grasping the fish; otherwise, the dry hand will remove the slime from the back of the fish. This slime is a protection to the fish, for the numerous microscopic plant spores that thrive on fish are unable to gain a foothold except where the slime has been removed. If these spores do get a foothold, they may kill the fish.

The fish that are large enough to be kept should be killed as soon as they are taken from the hook. They can be killed by a blow with a stick on the head, back of the eyes. This will prevent all suffering and make the fish far better for table use.

These two simple procedures are recommended by all the fish and game commissioners throughout the United States.

116. Vocational Possibilities. — In studying fishes, some of you may have wished that you might make them a life-long



New York State Conservation Commission

FIGURE 124. FREEING TROUT FRY

When the trout fry are large enough to take care of themselves, a suitable trout stream is found and they are placed in it.

study. The future of fish culture demands trained workers in every state in addition to the United States Bureau of Fisheries. Write to the conservation commission of your state for a detailed statement of opportunities.

SUMMARY

We pass now from the insects and from the similar but much simpler crustaceans to higher animals. This group is called the vertebrates and shall learn in the next few chapters why these animals are really higher than the wonderful bees and ants.

The vertebrate group includes large animals, when compared with insects, with an internal skeleton consisting of a backbone, a skull, and bones for the two pairs of appendages. There are always, at some stage in their life history, gills that are located on the edges of gill slits. These gills become absorbed in animals that live permanently on land and lungs are used to bring oxygen to the blood. Fish live in both salt and fresh water and are valuable as food to man. There are more than 12,000 different kinds of fish. In order to protect the spawning fish and their young, laws have been passed and hatcheries established by the government. There are many important biological problems involved in the study of fish, some of which will require many more years of investigation.

QUESTIONS

What are the chief differences between vertebrates and invertebrates? Are the gill slits of a fish ever found in land vertebrates? At what ages? Of what three parts does the body of a fish consist? What are the fins? the scales? Describe the life processes of the fish. Have fish any special senses? What is spawning? How do fish care for their young? How many kinds of fish do you know? Are they all good to eat? How important is the fish industry to man? What methods of fish protection are practiced and by whom?

TOPICS FOR DISCUSSION

1. Compare insects and fish. In what ways does one have an advantage over the other?
2. What would happen if all fish eggs hatched and grew to maturity?
3. What streams in your community are stocked?
4. Do sewage and the wastes of manufacturing go into these bodies of water? Do they hurt the growth of the fish?

5. Should there be any law limiting the number of fish that any one person may catch?
6. What should you know if you want to specialize in fish culture?

REFERENCES

Fish Manuals of the U. S. Commission of Fish and Fisheries
Harris, *Salmon and Trout*, The Macmillan Company
Henshall, *Bass, Pike, Perch and Others*, The Macmillan Company
Jordan, *Fishes*, D. Appleton and Company
Jordan and Evermann, *American Food and Game Fishes* (out of print)

CHAPTER XII

SALAMANDERS, FROGS, AND TOADS

*When by night the frogs are croaking,
Kindle but a torch's fire;
Ha! how soon they all are silent!*

— LONGFELLOW

117. Amphibians. — The most familiar examples of amphibians are frogs and toads; but the *salamanders* (săl'-ä-măn'fērz), frequently miscalled *lizards* (see § 132), also belong here. The *amphibians* (äm-fīb'i-ănz) are all small vertebrates,



FIGURE 125. A SPOTTED SALAMANDER

the largest one found in America being a salamander (*Cryptobranchus*) which is rarely more than two feet long. The word *amphibian* comes from the habit which frogs, toads, and certain salamanders have of spending their larval life (tadpole stage) in the water and their adult life on land, or partly on land and partly in the water.

LABORATORY STUDY

Place one or two frogs or toads in a small jar or box and observe the points mentioned in the report below. Record your observations on a table similar to the one below. Do not mark your book.

DO THEY WINK?	CAN THEY PROTECT THEIR EYES?	HOW DO THEY GET AIR?	CAN THEY WALK? HOP?	HOW DO THEY SWIM?	HOW DO THEY CATCH A FLY?

118. Frogs. — The general form of the body, the shape of the head, the long hind legs adapted for jumping, and the webbed

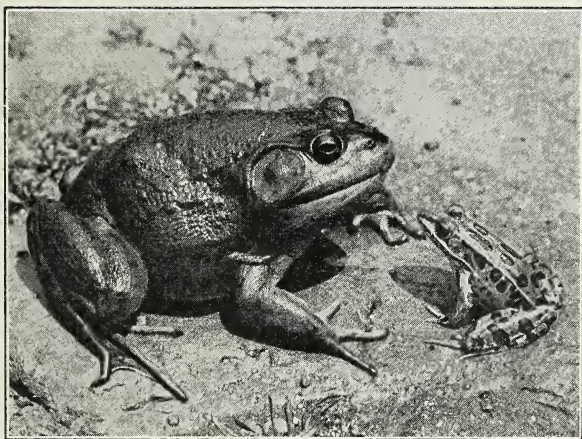


FIGURE 126. THE BULLFROG AND THE LEOPARD FROG

Can you explain why these two kinds of frogs do not live together?

toes for swimming are much the same in all frogs. There are several kinds, one of which, the leopard frog, is found generally distributed throughout the United States. It can be recognized by the many brownish or greenish spots, edged with white, on the

back, which help the frog to escape the notice of its enemies as it squats among the water weeds. These colors form rather definite bands on the hind legs, though there is much variation. Like other animals, frogs perform all the life functions.

LABORATORY STUDY

Compare the general shapes of fish and frog. How do the colors differ? Show how the legs and feet are adapted to the way the frog lives. Is the frog sensitive to touch in various parts of the body? Examine the eyes. Open the mouth and see that the frog can draw in its eyes. The ear membrane is on the side of the head back of the eyes. Pass a probe through the ear membrane of a dead frog and see where it comes out in the mouth. This is the opening of the Eustachian tube. How far can the living frog see? Notice the method of breathing. See the throat move up and down. Hold

the frog under the water and gently rub its sides. It will usually croak. Thus we can prove that the frog is able to make the air travel from its lungs to its mouth and back again while under water.



FIGURE 127. FROG CAPTURING AN INSECT

119. Food-Taking. —

Frogs are greedy creatures. They will eat almost any animal small enough to be swallowed, such as insects, worms, snails, tadpoles, and small frogs. These are caught alive and when in motion. The large mouth has short lips covering the

short teeth in the edge of the upper jaw. The sticky tongue has two fleshy horns at the back end, and is attached by the front end to the floor of the mouth. The frog can throw its sticky tongue over the tip of the lower jaw and use the forked end to catch insects, which are then carried into the back of the mouth. Two groups of little curved teeth in the roof of the mouth aid in preventing the escape of the prey. The food is swallowed whole.

Endeavour
1871-1873



LOUIS JOHN RUDOLPH AGASSIZ (1807-1873) was born in Switzerland and died at Cambridge, Massachusetts. He introduced the laboratory method in zoölogy to students in America and trained many who have become prominent in biology. His motto, *Study nature, not books*, has been taken as a motto by thousands of students all over the world. He was the founder of the summer laboratory method of study now so common, the first such laboratory having been established on Penikese Island off the coast of Massachusetts. He was professor of zoölogy and geology at Harvard and curator of the museum that now bears his name. His scientific contributions covered a wide range of subjects in zoölogy and geology.

✓ F.

✓ F.

✓ F.

✓ F.

✓ F.

✓ *proletum colloratus*.

120. Digestion. — The esophagus (the tube connecting the mouth cavity and the stomach) of the frog can be stretched so that a comparatively large animal can be swallowed. The



FIGURE 128. THE PART PLAYED BY THE FROG'S TONGUE IN CAPTURING INSECTS

esophagus enlarges into the stomach, which is a long, spindle-shaped sac (Figure 129), larger than the rest of the digestive tube.

The small intestine begins at the back end of the stomach as a small tube which makes several turns, and finally enlarges into a region called the large intestine, the last part of which is termed the *cloaca* (klō-ā'kā) or common sewer (Figure 130).

Two important glands belong to the digestive organs — the *liver* and the *pancreas*. The liver is a large, dark red, three-lobed organ that covers the *ventral* (lower) surface of the stomach. The pancreas is a whitish, small, irregularly shaped body attached between the stomach and the intestine. Both these glands drain into the intestine just beyond the stomach. The bile secreted by the liver is at first collected in a sac called the *gall bladder* (Figure 129).

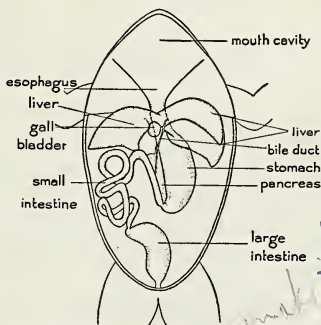


FIGURE 129. DIGESTIVE TRACT OF THE FROG

All these parts of the alimentary canal are held in place by a thin membrane, the *mesentery* (mēs'ēn-tēr-ī), one edge of which is attached on the *dorsal* (upper) side along the line of

the backbone and the other to the stomach and intestine. A small gland (the *spleen*) is found in this mesentery; it has no duct connecting it with any other organ in the frog, and is closely related to changes in the blood. Blood vessels connect with the spleen.

121. Respiration. — The lungs are hollow sacs that lie back of the stomach, one on each side (Figure 130). In the freshly killed

animal, these can be filled with air by inserting a blow-pipe into the windpipe and blowing air into them. When empty, the lungs are less than a half inch in diameter.

The oxygen of the air passes directly through both the skin and the lungs into the blood of the frog, and the carbon dioxide of the blood is thrown off through these same two organs. The frog has large blood vessels close to the skin, especially along the back. These send out many

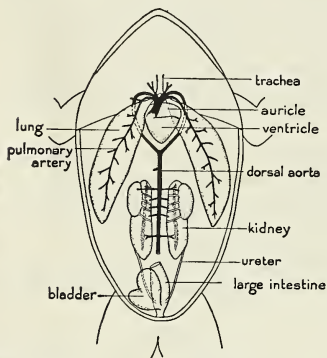


FIGURE 130. SOME ORGANS OF THE FROG

fine branches which enable the frog to "breathe" through its skin. When the frog remains under the water for a long time, as during the winter, all the oxygen used enters the blood through the skin. When air is taken into the mouth, it is swallowed into the lungs by the muscles on the floor of the mouth rather than breathed in as a frog has no diaphragm. Experiments have been made which show that the frog can get oxygen in sufficient quantities to maintain life, even if it has not the use of its lungs. The frog thus possesses two organs of respiration, the skin and the lungs, and can take oxygen from both the air and the water.

122. Nervous System. — In all vertebrates there is a well-developed nervous system, which includes brain, spinal cord, nerves, and sense organs described below. Animals with definite

nervous organs and a specialized brain as in the vertebrates are able to do more things and with more precision than a worm, for example. The brain of a frog is really a very simple organ when compared with the brain of a dog. This is the main reason why a dog can be taught to do so many more things than a frog.

The nervous system of the frog is more highly developed than that of the crayfish and in some respects more than the fish. It consists of a central part inclosed in the backbone and *cranium* (brain case). This central nervous system in all vertebrates is always found back of the main body of the backbone, and is divided into the brain and the spinal cord, from which numerous nerves arise and extend to all parts of the body.

The parts of the brain are the same as in man and much easier to study. (See Figure 131.) The *olfactory lobes* receive the smell stimuli. The cerebral hemispheres control muscular action. When the latter are removed, the frog

loses all power to think of movement and will sit still in a dry, warm room for hours unless disturbed. This he never does when the cerebral region of the brain is uninjured. The mid-brain region is the passageway for all nerve-pathways that travel to and from the brain. The mid-brain and optic lobes explain to the frog the sight stimuli. In the frog, the cerebellum, which is poorly developed, is less important than in man. The *medulla* gives off more nerves than any other region of the brain, leading to the face, tongue, ear, heart, and lungs. Though there is a great difference in shape between the parts of the frog's brain and those of man, the work done by the similar parts is of the same kind.

The brain joins the spinal cord without any external sign to indicate where one begins and the other leaves off. Ten pairs

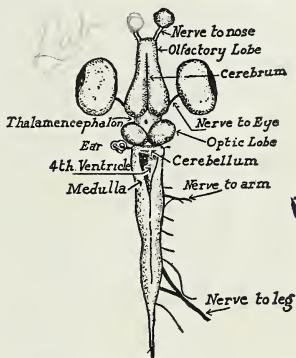


FIGURE 131. CENTRAL NERVOUS SYSTEM OF THE FROG

of nerves leave the brain proper. These are devoted to the special senses of the head and to moving the muscles of the throat and head. The frog has ten other pairs of nerves joined to the spinal cord (Figure 131).

The several parts of the brain are the same in all amphibians because the skulls or brain cases of all of them are similar, but the spinal cord in some amphibians, because of the much greater length of their tail regions, is more than twice as long as it is in the frog.

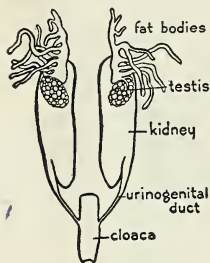


FIGURE 132. RELATION OF THE TESTES AND KIDNEYS TO THE CLOACA IN THE FROG

123. Excretion. — Like the fish, the frog has a pair of *kidneys* that removes wastes from the blood in the form of liquids; while the skin and lungs allow such wastes as the gas, carbon dioxide, to be discharged from the blood.

The kidneys are small red bodies lying close to the back. Each one is connected with the cloaca by a minute duct (*ureter* or *urinogenital duct*). The urinary bladder is attached to the cloaca (Figures 130, 132).

124. Reproduction. — The fundamental process of reproduction in the amphibians is the same as in all other animals, but there is introduced the tadpole stage which makes their life cycle different from that of any other vertebrate.

The male frog has a pair of *spermaries* (spûr'má-rîz), one attached to the front (anterior) end of each kidney (Figures 130, 132). Each spermary (*testis*) is yellow in color. The sperms pass through the kidney, through the urinogenital duct, into the cloaca, and out into the water. In the female frog, *ovaries*, sometimes filled with eggs, are easily seen. A long, closely coiled pair of *oviducts* (ō'vī-dŭkts) opens in front near the forward end of the stomach and in the back into the cloaca. The eggs break through the wall of the ovary and then pass through the oviducts, where they are coated with a jelly-like covering that swells in the water. This jelly covering protects the eggs.

At the front end of each kidney in both the male and the female frog is to be seen an irregular mass of fat, which contains stored energy that the frog uses as it begins to grow eggs or sperms in the early spring before there is plenty of food (Figure 132).

LABORATORY STUDY

In connection with the study of the frog, the following additional laboratory work should be done in order that the several organs of man which are discussed in Unit IV may be better understood. Frogs that have been preserved in formalin can be easily dissected. Wash them well in water to which ammonia has been added. Examine the digestive organs: first the mouth, then the esophagus, stomach, small and large intestine, and cloaca. For convenience, the liver will have to be removed. The pancreas can be seen as a small whitish structure in the loop between the stomach and the intestine. The spleen is a round red organ usually found near the large intestine.

A pair of narrow kidneys lies close to the back. They are connected by ducts with the cloaca. A spermary is found attached to each kidney near the front end and the sperm cells escape to the exterior by the kidney ducts. In the female frog the large ovaries occupy most of the space of the body cavity. A pair of oviducts opens into the body cavity just back of the stomach. The eggs escape from the ovary into the body cavity.

The nervous system is inclosed in bone that is easily removed from the dorsal surface. The brain should be studied and the following divisions recognized: cerebral hemispheres ending in front in the olfactory lobes, which are not clearly marked. Just back of these are the two large roundish optic lobes which are attached to the mid-brain. The cerebellum is small and the medulla passes into the spinal cord without any sharp dividing line.

125. Life History of the Frog. — In the early spring the frogs gather in ponds to lay their eggs. The eggs are surrounded by a jelly-like substance which holds them together. As the eggs are being laid by the female frog, the male frog spreads a large number of sperm cells over the whole mass. These sperm cells make their way through the soft jelly and one of them must enter each egg if the egg is to grow normally into a tadpole.¹

¹ Scientists have been able to make the egg segment and grow, under special care, until the tadpole stage, so it has become necessary to say that normally or in nature the egg will not grow unless a sperm cell unites with it.

Fertilization of the Egg. — As soon as the sperm cell enters the egg (Figure 134), it begins to change from a solid, pointed body into a round nucleus which is so much like the nucleus already



FIGURE 133. EGG MASSES OF THE FROG

in the egg cell that none but experts in this study can tell which came from the sperm cell and which from the egg cell. These two nuclei come in contact and unite, leaving but one nucleus in the egg (Figure 134). This last change is *fertilization*, which is defined as *the union of the contents of the egg and the sperm nuclei*. This union consists in bringing the *chromosomes*¹ of the two

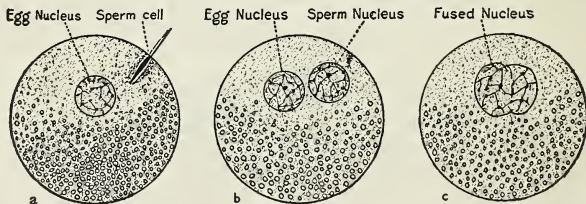


FIGURE 134. FERTILIZATION OF A FROG EGG

The sperm cell is penetrating the cytoplasm of the egg (a); the head of the sperm cell has become transformed into a nucleus (b); the egg nucleus and the nucleus derived from the sperm head fusing (c). This fusing is fertilization.

¹ The technical term, *chromosomes*, is the name for definite bodies within the nucleus.

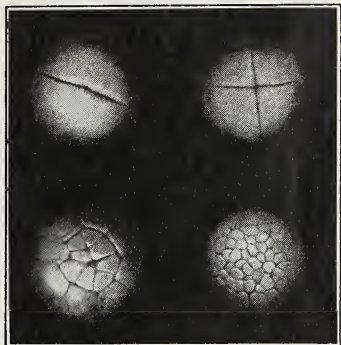
nuclei together so that there is a definite part of each parent present in this fusion. (See Figure 134.) After this union is completed the egg begins to divide into cells, as shown in Figure 135, and finally the tadpole is grown.

Growth of the Tadpole. — As soon as the young tadpole hatches, it attaches itself to plants and lives for the first few days upon the food-yolk within its own body ; the mouth forms, and horny jaws develop. Then the tadpole begins to feed upon minute plants and becomes dependent upon its own skill to get food and escape its enemies.

For a time the tadpole breathes through gills. Two sets are used. The first ones are on the outside of the body and last for only two or three days. Then internal gills form in the throat and the tadpole breathes much like a fish.

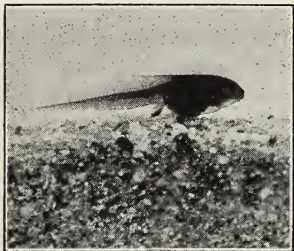
As the tadpole develops the hind legs appear first. Later the front ones begin to show and as they develop the tail is gradually absorbed. While these external changes are going on, there are many complicated internal changes taking place ; internal gills are disappearing and lungs, nerves, blood vessels, and muscles are being formed to give the new legs life and action. The internal lungs take the place of the gills in the throat before the legs are fully grown, and such tadpoles must rise to the surface to breathe air. (Explain which tadpoles in Figure 136 breathe by lungs and which by gills.) This complicated way of growing into a frog is called *metamorphosis* and this term has the same general meaning as when used to describe the growth of insects (§ 51).

The tadpoles of leopard frogs become small frogs in a single summer, but the tadpoles of bullfrogs and green frogs require

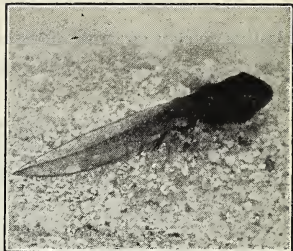


B. G. Smith

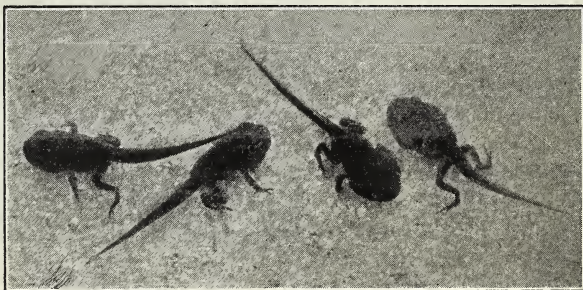
FIGURE 135. SEGMENTING SALAMANDER EGGS



As soon as the eggs hatch, the tadpole begins to swim about like a fish.



In a few weeks the hind legs appear.



These hind legs are followed by fore legs.



The next change to watch for is the loss of the tail and the changed habits of breathing.

FIGURE 136. THE METAMORPHOSIS OF A FROG

two seasons to complete their development. These latter tadpoles hibernate in the mud with adult frogs and toads.

Toward the end of fall, frogs prepare to spend the winter dormant. Sometimes in the middle of the day they may be seen sunning themselves on a bank, but as soon as ice forms on the water they remain on the bottom or buried in the mud. The lungs are emptied of air, the heart beats decrease, and all the usual life processes take place more slowly. All the Amphibia and reptiles, and several of the mammals hibernate during the winter.

126. Enemies and Means of Protection. — Frogs are seldom found far from the marshy edges of some pond or stream. When disturbed, they jump into the water, swim to the bottom, stir up the mud, and quietly come to rest a short distance from the place where they entered. They are protected also by their color, which usually resembles the grass and rocks among which they live. When away from water, frogs often escape their enemies by their remarkable leaping ability. As the frog's hind legs are considered a delicacy, man is the worst enemy of the larger frog. Next come the snakes, birds, and fish. The leech kills frogs by sucking their blood. Fish eat many of the tadpoles, and, strange to say, some water beetles eat tadpoles also.

127. The Toad. — This homely animal is one of our best friends, for he lives on insects and slugs that destroy the plants in our gardens. He captures his food by throwing out a sticky tongue just as the frog does.

One often hears the expression, "Don't touch a toad, you will have warts." Of course this is not true, nor is it true that they are found alive in solid rocks. They require food like all other animals and soon starve unless they can secure it.

128. Life History of the Toad. — In many respects the toad's life history is similar to that of the frog. In the spring, the eggs of the toad are laid in stagnant water in strings of a jelly-like substance (Figure 137). The eggs hatch in from five to ten days into wriggling tadpoles, which feed on the microscopic plants in the water and swim by means of their tails. Respiration is

accomplished by means of the outside gills, which allow the oxygen from the water to reach the blood and the carbon dioxide to enter the water. Later the inside gills take over the work of



FIGURE 137. STAGES IN THE LIFE HISTORY OF THE TOAD

the outside gills and the outside gills disappear. Still later, as lungs begin to develop, the tadpoles come to the surface for air, so that for a time they are getting the oxygen from both the air and the water. (See Figure 136.)

About this time the hind legs begin to appear, the tail shortens and, soon after, the front feet may be seen. By the first of July the tail has entirely disappeared and the small toad begins to hop around on the bank, having the form, attitude, and habits of



FIGURE 138. A TOAD

the toad as we see him in the garden. From the bank they begin to travel away from the water and scatter over the country in all directions. After a rain or during a shower, thousands of them are sometimes found hopping along a ravine or highway. Here they are run over by man and beast and fed upon by crows and other enemies.

Of the hundreds that leave

the pond but very few ever live to be a year old. Although slow-moving, the toad is able to feed upon many flying insects,

which he strikes with his quickly moving tongue as they rest on plants or crawl over the ground.

129. Economic Value of Amphibians. — The toad is the only amphibian that is of any great value to man. It eats many destructive insects. Frogs eat a few, but hardly enough to entitle them to high rank as beneficial animals. Their chief value is as food and as convenient forms for dissection in biology courses.

SUMMARY

The highly specialized insects and the fishes which represent rather simple vertebrates both show fascinating adaptations, but neither suggests how animals may have become land dwellers. Examine again the life cycle of the frog and see whether the tadpole is more like a fish or more like a frog.

The amphibians live both on land and in water. The best known are frogs and toads, and salamanders, frequently miscalled lizards. The frog has all the life processes of the other animals we have studied, though of course these vary in the way each is carried out. The brain and nervous system of the frog are much more highly developed than those of the crayfish. The parts of the brain are the same as in man.

The life history of a frog begins with the eggs, which are laid in ponds early in the spring. After fertilization, the egg develops into a tadpole which gradually grows legs and loses its tail. Meanwhile complicated changes take place inside. Frogs have protective coloration and in winter they hibernate.

The toad has practically the same life processes and life history as the frog. It is of greater economic importance to man because of the large number of insects it eats.

QUESTIONS

Each member of the class should bring in a set of questions on this chapter. Explain why one set happens to be better than some of the others.

SPECIAL TOPICS FOR DISCUSSION

1. Compare salamanders with fishes. What adaptations does each kind of animal show?
2. How would you change a salamander to make it into a fish?
3. Explain how the frog can live under the water all winter.
4. Which has the superior sense organs, the frog or the grasshopper?
5. Can you suggest how animals came to live on land?

REFERENCES

- Dickerson, *The Frog Book* (out of print)
Hodge, *Nature Study and Life*, Ginn and Company
Holmes, *Biology of the Frog*, The Macmillan Company
Marshall, *The Frog*, The Macmillan Company
Morgan, *Embryology of the Frog* (out of print)
Smallwood, *Textbook of Biology*, The Macmillan Company

CHAPTER XIII

THE REPTILE GROUP

But the trail of the serpent is over them all.

— MOORE

130. Life History. — The reptiles hatch directly from eggs into the adult form, only much smaller. They do not go through several larval stages like the insects and amphibians. The young snake or alligator just out of the egg is readily recognized by its



Antivenin Institute of America

FIGURE 139. A SINGLE BROOD OF THE CENTRAL AMERICAN PIT VIPER

resemblance to its parents. The reptiles lay their eggs in protected places but exhibit no parental care for either eggs or young. The eggs of some snakes are hatched in the body of the parent and the young are born alive.

131. Turtles. — Every one knows the common spotted turtles. They are easily recognized by their outer skeleton. The skeleton of turtles is unlike that of the insects or crab or any other group of animals. The skeleton of the turtle, composed mostly of skin plates, is somewhat like a box with a cover, the lower portion corresponding to the box itself, and the upper portion to the cover. The cover does not fit closely all the way around, for there are places where the head, the tail, and the four legs stick



FIGURE 140. BRINGING IN SEA TURTLES

What uses are made of them?

out. When the turtle is disturbed, the legs, the head, and the tail are drawn inside, and the cover is pulled down tightly by muscles.

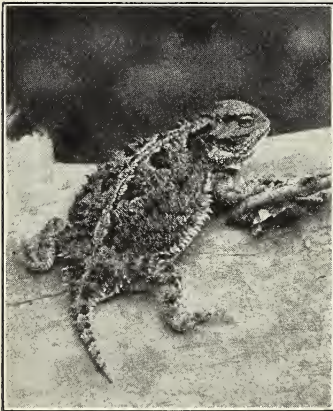


FIGURE 141. HORNED TOAD OF THE SOUTHWEST

It is really a lizard.

Sea turtles attain a length of six or eight feet and weigh sometimes as much as a thousand pounds. The flesh of the green turtle and of the diamond-back *terrapin* (těr'ă-pĭn) is esteemed as a delicacy. The snapping turtle common in the United States has sharp horny jaws capable of a severe bite. They are carnivorous.

132. Lizards. — There are several varieties of lizards, one of the commonest of which is the chameleon (*kă-mě'lě-ăn*), which has the extraordinary ability of changing the inten-

sity of the color in the skin by moving the color material nearer the outer surface or drawing it away. The horned toad of the western United States is a lizard with scales of varying length which give it a horny appearance. Horned toads, instead of laying eggs, hatch the eggs while they are in the oviducts, and the young are born alive. A poisonous lizard is the Gila (hē'lá) monster that occurs in New Mexico and Arizona. The poison glands are in its lower jaw.

133 Snakes. — Snakes are legless vertebrates with long, cylindrical bodies covered with scales. They move by means of the scales (*scutes*) on the under side of the body. Since snakes eat insects, mice, rats, and rabbits, they are considered beneficial.

Rattlesnakes ¹ and copperheads are the most common poisonous snakes of our country. Their jaws are provided with fangs (Figure 142), by means of which a poison is injected into their prey. Large snakes, like the boa constrictor of South America and the python (pī'thōn) of Asia, are constrictors. They are able to wind their bodies around their prey and to crush it to death. The

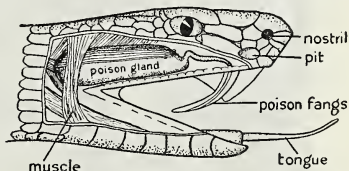


FIGURE 142. DIAGRAM OF THE HEAD OF A RATTLESNAKE, SHOWING POSITION OF POISON GLAND AND FANGS

most deadly snake in the world is the cobra (kō'brá) of India, where thousands of the inhabitants die annually from its bite. It is the only snake that pursues man when not attacked by him.

Snakes swallow their food whole, and as the teeth are used merely for holding their prey, they point backwards.

Fear of Snakes. — In the case of many grown-up people there is a senseless fear of even the smallest snake. Small children are seldom afraid of snakes until some older person tells them that snakes are poisonous or that they bite. As a matter of fact the small snakes of the garden will not bite when carefully touched,

¹ The two most common rattlesnakes are the mountain rattler and the massasauga (mās'á-só'gá).

but seem rather to like to be handled. When one stops to think that snakes, like all reptiles, are cold-blooded, while the hands are warm, it is not strange that they might come to enjoy the human hand. It is unwise to put fear where there should be none. Fear takes a toll of our nervous energy, and if we can learn to banish senseless fear, we have done something towards improving life.

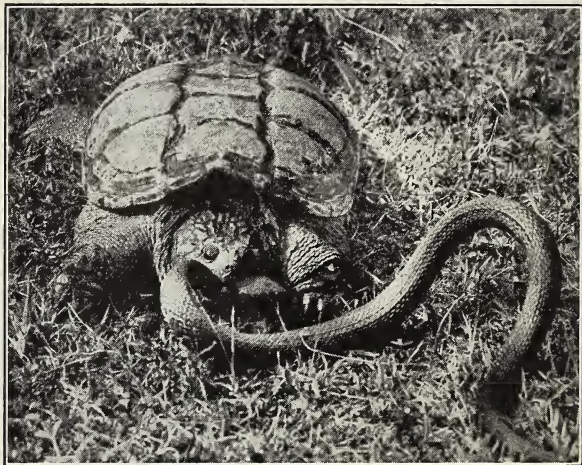
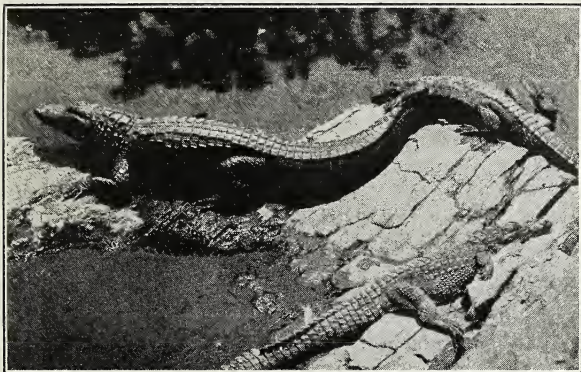


FIGURE 143. A STRUGGLE BETWEEN A WATER SNAKE AND A SNAPPING TURTLE
Which will win this battle?

134. Crocodiles and Alligators. — Crocodiles are found in the southern United States, South America, Africa, and India. Alligators are found in stagnant pools in the southern United States. Crocodiles resemble alligators but have narrower mouths.

135. Adaptations of Reptiles. — The following examples will show that reptiles are well adapted to their environment. Snakes that live in trees are sometimes of the color of leaves or bark. Some that are harmless are colored much like poisonous snakes. An adaptive feature of the crocodile is a fold of skin which shuts

off the mouth from the throat and prevents water from entering the throat while the crocodile is drowning its prey. The old-world chameleons have their feet modified for clasping branches.



Courtesy New York Zoological Society

FIGURE 144. ALLIGATORS

Compare them with the tortoise and the lizard.

Marine turtles have paddle-like feet for swimming, while those that live partly on land and partly in the water have toes with webs. Lizards are almost always of about the same color as their surroundings.

LABORATORY DIRECTIONS

From models or preserved specimens the difference between the harmful and harmless reptiles should be worked out. The living turtle can be studied easily. Its special skeleton is an illustration of protective adaptation. Notice how the nostrils of the aquatic turtle can be closed. How does this help the turtle?

SUMMARY

The reptiles always use lungs for breathing. They usually have scales or bony plates in the skin and have either two pairs of appendages (turtles, lizards, alligators, crocodiles) or none (snakes). The young of reptiles resemble the parents as soon as they hatch. It is important to learn to recognize poisonous reptiles.

QUESTIONS

What are the most common snakes in your vicinity? Are they poisonous? How can you tell? Where do they live? What do they eat? How many kinds of turtles do you know? Where do they live?

SPECIAL TOPICS FOR DISCUSSION

1. Why do we say that reptiles have become nearly extinct?
2. When was the "Age of Reptiles"?
3. What is the difference between a salamander and a lizard?
4. What is the difference between a frog and a turtle?
5. Did snakes probably once have legs?

REFERENCES

Ditmars, *The Reptile Book*, Doubleday, Doran
Jordan, Kellogg, and Heath, *Animal Studies*, D. Appleton and Company
Linville and Kelly, *General Zoölogy*, Ginn and Company
Reese, *The Alligator and Its Allies*, G. P. Putnam's Sons
Reese, *Alligators as Food* (out of print)

CHAPTER XIV

BIRDS

*Among the dwellings framed by birds
In field or forest with nice care,
Is none that with the little wren's
In snugness may compare.*

— WORDSWORTH

136. Famous Students of Birds. — Everybody likes birds, and you have now reached a point in your work in biology where you are ready to make a systematic study of them. First you must understand how birds are classified so that when you observe them carefully you will be able to compare the results with what others have found out. Birds are interesting to so many people that we are giving you the pictures of three men who have done a great deal to make us familiar with the habits and appearance of the more common birds.

137. Methods of Classifying Birds. — Birds show the widest diversity in size and mode of life, from the tiny nectar-eating humming bird to the broad-winged eagle. Birds are usually classified according to their structure. The shape and size of the beak, feet, and wings are the characteristics most used. In addition, they are also classified by their habits. For example, birds are divided into four classes based on their migratory habits. Birds like the downy woodpecker and English sparrow are permanent residents throughout their range, while bobolinks and humming birds are summer residents. Birds like wild geese and fox sparrows are transients, stopping along their migratory route for rest or food or to escape unfavorable weather; while such birds as the snowy owl, northern shrike, and evening grosbeak (grōs'bēk) are winter visitants.

Birds can be classified also by their nesting habits. Some, like the meadow lark and bobolink, nest in the open field, and



FIGURE 145. FEMALE EVENING GROSBEEK (*left*) AND YOUNG KINGFISHER (*right*)
Where does the grosbeak nest? Is a kingfisher, which is just old enough to fly, expert enough to catch fish?

their nests are made difficult to see rather than difficult to reach ; others, like certain hawks and eagles, build their nests in tall trees, making them conspicuous, but inaccessible. Still others build like the oriole at the end of slender branches, where they are out of reach of animals. Birds like the kingfisher and bank swallow build their nests at the bottom of a burrow in a bank.

138. Adaptations and Structure of Birds. — The front legs of birds are modified into wings. Among some birds, like the penguins (pĕn'gwĭnz) of the antarctic region, the wings are used not for flying but to assist in swimming. In others, like the eagles and

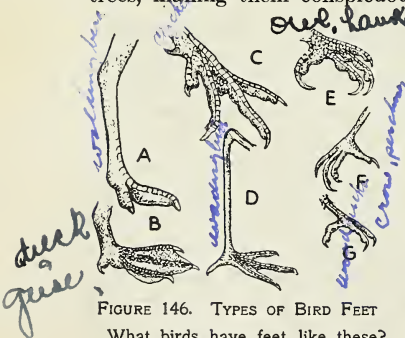
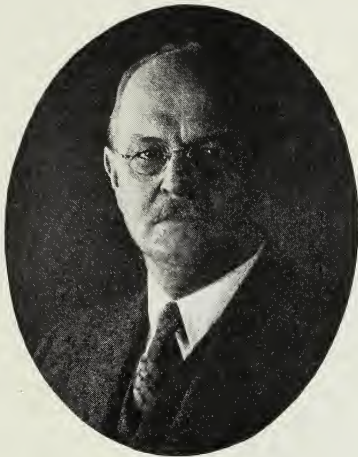


FIGURE 146. TYPES OF BIRD FEET

What birds have feet like these?
Are any of these like a woodpecker's foot?



FRANK M. CHAPMAN (1864-) was born in Englewood, New Jersey. During the World War, he was Director of the Bureau of Public Relations for the American Red Cross. Except for this period of four years, his life interest has been the study of birds. His success in this field of zoölogy has brought to him gold medals and the presidency of several organizations. Dr. Chapman has written many books on birds. Among his best-known are *A Handbook of Birds of Eastern North America*, *Bird Life*, *Bird Studies with a Camera*, and *The Economic Value of Birds to the State*. He is the founder and editor of *Bird Lore*. His whole life has been devoted to his desire to make more people appreciate the economic and esthetic value of birds.



condors, the expanse of the wings is enough to enable them to fly away with young lambs and young deer. Between the wings of the penguin and those of the eagle there are many variations.

Sailing birds, like the gulls, have long, slender wings, while ground birds, like the partridge and pheasant, have short wings capable of rapid, short flights. Those birds that use their wings most have them best developed. An example of underdevelopment, which has been increased by domestication, is seen in the domestic fowl, a ground bird, which makes little use of its flying powers, and is incapable of long flights.

Legs also show many variations. In the case of eagles, hawks, and owls the toes end in powerful claws for seizing and holding prey, while ducks and geese have long and webbed toes, adapted to swimming. Seed-eating birds have weak toes which serve merely for perching. Chimney swifts (Figure 147) have feet adapted for clinging. (Figure 146.)

The beaks of birds also show great variation and adaptation for defense and food-getting. Hawks, owls, and eagles have the upper jaw curved over and hooked for tearing their food; herons and bitterns have the beak modified into a long, pointed weapon of offense and defense; grosbeaks and finches have a short, stout beak for crushing seeds and other hard foods; while humming birds have a long, slender beak which in some kinds is curved so that they may reach the bottom of certain flowers. Study Figures 19, 145, 154, and 168.



FIGURE 147. THE CHIMNEY SWIFT WITH HER YOUNG AND HER NEST

The sticks of the nest are fastened to the barn and to one another. Have you ever seen a swift break off sticks from a tree as she flies?

Structural Characteristics. — The birds show a number of other interesting adaptations which are of use to them. These are hollow bones, a keeled breastbone, and a high body temperature.

The skeleton of a bird shows a prominent ridge on the breastbone. This is the keel which serves as a place of attachment for

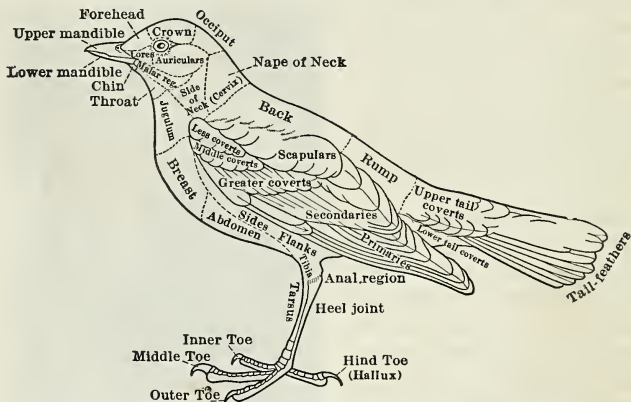


FIGURE 148. REGIONS OF A BIRD'S PLUMAGE THAT SHOW AREAS OF DEFINITE COLOR LOCATION IN CERTAIN SPECIES

the large, active wing muscles. The lungs of the bird are small, but air tubes extend into the bones, so that its body is lighter than that of animals with solid bones.

Birds lead an active life, and for this reason they use a great deal of energy. This energy comes from the oxidation going on in the body. In birds, oxidation is more rapid than in other vertebrates, because they almost completely change the air with each breathing movement and thus secure a greater supply of oxygen. The rapid oxidation requires that a large supply of food be digested and assimilated rapidly, and it makes the normal body temperature of birds higher than that of other vertebrates.

Plumage. — Birds are the only animals having feathers, and

their plumage shows great variety in form and color. In some species there are certain colors which always predominate on the males, while the females have little color; in other species it is hard to distinguish between the sexes. The brilliantly colored males are supposed to attract the females at the mating season, while the dull-colored females are inconspicuous and less likely to be attacked by enemies while hatching their eggs or caring for their young. We may say, therefore, that they are protectively colored. The color of birds varies during the first two or three years of life.

139. Nest-building. — Nests vary from very elaborately constructed ones to mere depressions in the grass. Some birds build a large nest with materials loosely put together, others build small nests of neatly woven material, and some birds, like cowbirds, build no nest at



FIGURE 149. FEMALE WOODCOCK INCUBATING

Can a woodcock see behind her head without turning it?

all, but lay their eggs in the nests of other birds and leave the work of caring for their young to the foster parents.

The number of eggs laid in a nest varies from one to as many as thirty or forty. The eggs hatch in from ten days to six weeks. Birds whose eggs hatch in ten days or two weeks are called *altricial* (ăl-trîsh'ăl), for such young are hatched helpless, blind, and with little down. Eggs that hatch in from three to six weeks develop well-formed young, able to run around within ten or twelve hours after hatching. These are known as *præcocial* (prê-kō'shăl). Such birds have little need for a substantial nest and only a few of them build one. The robin is altricial, and the domestic fowl præcocial.



FIGURE 150. SPARROW'S NEST WITH COWBIRD'S EGG

The large egg was laid by the cowbird. The four smaller eggs belong to the chip-ping sparrow. Have you ever found any cowbirds' eggs?

STUDY OF A LIVING BIRD

Have a member of your class bring a canary or other caged bird to school for observation. Questions about the bird may be asked and answered by members of the class. The following are typical questions that may be used:

1. How many toes has the bird?
2. Are these toes grouped, two in front and two behind, or three in front and one behind?
3. Are the toe nails long or short? Are they used for taking food, for holding food, for perching, or for what?
4. How are the feathers distributed?
5. Where are the long feathers? Where are the short feathers?
6. Does the bird walk or hop?
7. Are the feathers evenly colored? Examine the molted feathers in the cage.
8. Examine the beak. Is it adapted for crushing seed, tearing flesh, catching insects, drilling?
9. Examine the feet. Are they adapted for tearing flesh, scratching, wading?
10. Examine the eyes. Does the bird wink?
11. Does the bird have eyelashes? Describe them, if any are found.
12. Can you find a third eyelid? Describe it, if it is found.

13. What are the colors of the head, back, tail, breast, throat?
14. Are there any special markings, such as head bands, shield spots, splashes of color, or any other striking color features?
15. How many kinds of sound does the bird make, such as different songs, alarm notes, call notes?
16. How does the bird drink?
17. How does the bird eat?
18. What and how much does it eat?
19. How does the bird bathe?
20. How does the bird "dust"?

140. Economic Importance of Birds. — The chief food of many birds is insects, and so they are beneficial to man, for they kill insect pests that destroy crops, especially in the south and west. Other birds, however, that eat food needed by man, or that destroy small and more useful birds, may be termed harmful. Domestic birds are valuable for the food which they supply or for their beauty of song or plumage.

Beneficial Wild Birds. — Birds such as quails, crows, red-winged blackbirds, kingbirds, shrikes, bluebirds, blue jays, pheasants, and many others feed on grasshoppers. Army worms, which are harmful almost without exception, are food for quails, vesper sparrows, song sparrows, and pheasants. The flicker eats ants by the thousands. Cuckoos are the enemies of caterpillars and canker worms.

Among the hawks and owls are found many beneficial birds, for the screech owls, red-tailed hawks, red-shouldered hawks, together with shrikes, destroy such harmful rodents as mice, shrews, moles, prairie dogs, woodchucks, and rabbits. The



FIGURE 151. NORTHERN SHRIKE

He is about to swallow a portion of the dead house sparrow fastened to a tree stub. Where does this bird nest?

hawks prey upon them during the day and at night the owls continue the slaughter. The shrikes feed upon mice to a great extent.

Aside from their value in destroying insects, birds are valuable as scavengers. The buzzards and vultures of the south and



FIGURE 152. JUNCO AT A FEEDING STATION

Does the beak indicate a seed eater or a prober?

west eat dead animals. The gulls of the sea and lakes eat refuse thrown upon the water. Crows eat dead fish.

One group of birds lives largely on seed, and these birds, for example the tree sparrows, redpolls, song sparrows, juncos, pheasants, and quails, destroy tons of weed seed during the fall, winter, and spring. In doing this they have a distinct value to agriculture.

Harmful Birds. — Not all birds are beneficial to man. Some birds are beneficial a part of the year, and more or less harmful at other times. Whenever the taste of a bird is like our own, it takes our foods. For example, a robin will eat cherries and berries which we are raising for ourselves.

Some of the smaller hawks, such as the sharp-shinned hawk and Cooper's hawk, are fond of small insect-eating birds and the young of our domestic fowls.

Domestic Birds. — Man has domesticated many kinds of wild birds. Chickens, turkeys, ducks, and geese have been developed for food. Peafowls (peacocks), pheasants, and canaries have been developed for their beauty of color or song. Parrots have been trained to speak.

All the kinds of chickens have been developed from the wild jungle fowls of India. Some of these are better as food, others as egg-layers. Most of our ducks and geese have been developed from the wild forms of Europe and Asia. Doves have come from the wild pigeons of Europe and Asia. From Africa we have taken the guinea fowl. The turkey is the only popular domestic bird that our own continent has contributed.

Canaries have been developed from wild birds from various parts of the world. Thousands of canaries are bred every year in the Harz mountains of Germany. Most parrots have been captured in the wild state; they are not bred as canaries are.

141. Growth of Bird Protection.—As the population increases it encroaches on forest and waste land and other favored nesting sites of birds. To prevent the extermination of desirable birds, we must protect them against the losses caused by advancing civilization. The available agencies for this work of conservation may be divided into three classes: (1) federal, (2) state, (3) private.

Work of the Federal Government.—The government of the United States has passed laws that have greatly helped conservation of birds.

The Lacey act, as amended in 1909, enables the Secretary of Agriculture to regulate the importation of birds and forbids the shipping of birds from a state where it is illegal to kill them.

The migratory bird treaty act of 1918, passed to give effect to the convention of 1916 between the United States and Great Britain, makes it unlawful to capture, kill, sell, or transport any migratory bird, or any part, nest, or egg of such a bird, except during the open seasons established by the Secretary of Agriculture. (A similar law is in force in Canada.) Under this law, open seasons are provided for ducks, geese, swans, rails, sandpipers, and others. Thrushes, orioles, swallows, wrens, and woodpeckers are always protected and cannot be taken at any season. For example, the robin, which is a thrush, may not be



FIGURE 153. MALE RUFFED GROUSE ON DRUMMING LOG

An enemy has torn off some of his tail feathers. A few days later he was killed on his drumming log. How does this bird drum?

killed anywhere in the United States. A state law making an open season for robins would be a violation of the federal law.

Another aid to bird protection is a section of the tariff act of 1913 by which "the importation of aigrettes, egret plumes or so-called osprey plumes, and the feathers, quills, heads, wings, tails, skins, or parts of skins, of wild birds, either raw or manufac-

tured, and not for scientific or educational purposes, is hereby prohibited." This act does not apply to ostrich feathers or feathers or plumes of domestic fowls.

Yellowstone National Park contains more than 2,000,000 acres. This is a famous game preserve and all animals are protected there. Glacier National Park contains over 800,000 acres. The Wichita National Game Preserve in Oklahoma contains 57,000 acres. Yosemite National Park in California contains 719,000 acres. No hunting is allowed in any of these parks and preserves.

Throughout the United

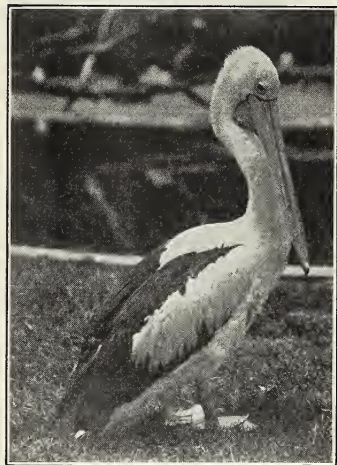


FIGURE 154. A WHITE PELICAN

This bird lives in the south. What is the use of the large beak?

States, including Alaska and various islands in the Atlantic and Pacific, there are more than 100 other bird refuges and game preserves. What bird refuge is nearest your home?

Work of the States. — Each state has the power to extend protection through laws which aid in the propagation of birds within its borders.

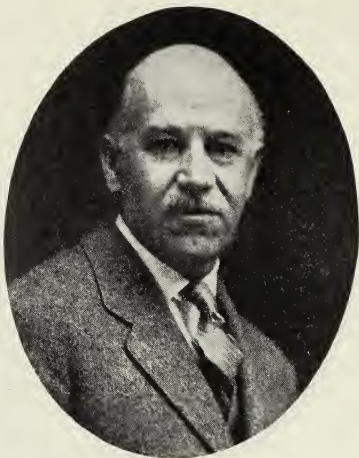
New York has a splendid conservation law on its books, which forbids the sale of all native wild game birds in New York State no matter where they are taken.



JOHN JAMES AUDUBON (1780-1851), self-trained naturalist, supported his family by drawing portraits. His father was a French naval officer and his mother partly Spanish. He spent a few years in France, where he gave most of his energy to music, drawing, and natural history during the period when he was in training for the navy.

After his return to America about 1800, he became a wandering naturalist, ever seeking for new birds to study. As he went from place to place, he would pay for his lodgings or a new pair of shoes by making a portrait of some local celebrity or even of the shoemaker himself.

His most famous work consists of one thousand and sixty-five natural-sized, colored figures of American birds, the publication of which alone took ten years and cost \$100,000. When you visit a large library, ask to be shown Audubon's *Birds*, the most noted book on American birds.



LOUIS AGASSIZ FUERTES (1874-1927) was born in Ithaca, New York. His main interest all through his high school and college life was birds. He almost lived with them and came to know them intimately. He learned to imitate their calls and in this way could bring them to him for intimate study. Later, he studied drawing and painting so that he could portray them in color. He traveled over many countries to learn of the other birds of the world.

Fuertes illustrated numerous books. Among them may be mentioned Coues' *Key to North American Birds*, Eaton's *Birds of New York*, Burgess's *Bird Book for Children*, and Burgess's *Animal Book for Children*. In his later years, he had more calls for his talents than time would allow him to answer. He stands at the head of the bird artists of the world. For a more extended story of his life, read *The Auk* for January, 1928.

Most of the states have special officers called game wardens to enforce the game laws.

Work of Private Organizations. — The laws passed by the federal government and the various states have originated and have been pushed by organizations of citizens interested in conservation. The National Association of Audubon Societies is one of the most energetic and powerful of the organizations.

Most of the ornithologists of the country belong to the American Ornithologists' Union, a national organization composed primarily of bird students. They study problems pertaining to birds, such as their distribution, migration, economic importance, and habits.

Work of Individuals. — A government may pass conservation laws, but it is public sentiment that compels their enforcement. In other words, it is necessary for the individual to do his part in supporting and respecting the various laws.

Some individuals of means have purchased lands suitable for breeding grounds, where ample protection is afforded either by state officials or by privately hired protectors.

The Ward-McIlhenny Bird Preserve of 13,000 acres in Louisiana is an example of such an area. Here thousands of ducks, geese, herons, and egrets are allowed to breed and live without being disturbed in any way. In February, 1929, the Mountain Lake Sanctuary established by Edward Bok was opened. It is located in Florida and is one of the most beautiful spots in the United States.

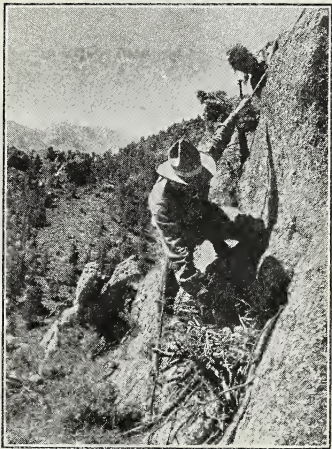


FIGURE 155. EAGLE'S NEST IN ROCKY MOUNTAIN NATIONAL PARK

142. Some Common Birds. — In most states there are probably between 200 and 500 kinds of birds found during the year. California with its great extent from north to south offers a larger variety in environment than any other state in the Union. No



FIGURE 156. BIRD SANCTUARY AT LAKE WALES, FLORIDA

doubt it leads in this aspect of its bird life; more than 500 varieties have been identified in this state. In New York State not more than half that number have been recorded.

We may select from these large lists certain representative birds for study.

The *bluebird* is found in orchards, fields, roadsides, and second-growth woods throughout the greater part of the United States. It is about seven inches long. The upper part of the male, including wings and tail, is bright blue. The breast and throat are of cinnamon color. The female is grayish blue above and paler than the male below. This bird nests in holes in trees and fence posts and is readily attracted by nesting boxes put up in orchards and woods. Its food consists of caterpillars, grasshoppers, crickets, and, in cold weather, some flying insects that are benumbed by the cold.

The *catbird* is nearly nine inches long and of a slate-gray color. The crown and tail are black. This bird is friendly and builds its nest near human habitations quite as often as in the woods. Catbirds are merely summer residents in the North, arriving latest in the spring and leaving earliest in the fall. They devour large numbers of insects and sometimes take berries and cherries. This privilege they have earned by their services in destroying insects. The note from which their name is taken is a very harsh cry. In addition they can sing sweetly and mimic other birds well.

The *crow*, — “black as a crow” describes this bird pretty well, though it has bluish and purplish lights on its black feathers. A mature crow is nearly twenty inches long. It is usually classed

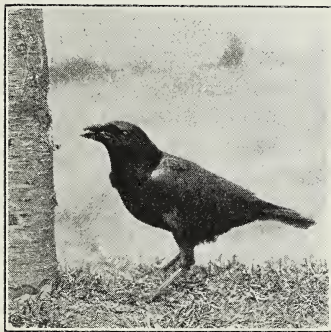


FIGURE 158. A CROW

The wary crow did come to the feeding station to eat. Are crows usually seen about feeding stations?



FIGURE 157. A MALE BLUEBIRD

This bird is bringing a caterpillar to his family in the hollow post. Would you class this bird as helpful or harmful?

as a permanent resident in the northern states. It is quite likely, however, that the crows which nest in the northern states go south in the winter and that their places are taken by winter visitants from Canada. These winter crows usually roost together in rookeries, where thousands are sometimes seen. They live in the deep woods, roadsides, orchards, and parks. They feed upon grasshoppers and other insects and young birds. They have been known to eat the

eggs of some of our valuable song birds. The crow, therefore, is partly helpful and partly harmful.

The *chickadee* is only $5\frac{1}{2}$ inches long, but its great activity makes it valuable out of proportion to its size. It eats the eggs, larvæ, pupæ, and adults of a long list of insects. Being a permanent resident within its range, it does most effective work every month of the year. The bird is attractively marked with black and white. The top of the head has a black cap. It comes to the yards and orchards freely in the winter time, and its spirited notes of "Chickadee-dee-dee-dee" make it a conspicuous and welcome visitor. It nests in a hole of a tree or stump and sometimes in a nesting box.

The *Baltimore oriole* is about $7\frac{1}{2}$ inches long and is very noticeable because of its plumage. The colors are black and orange, striking in the male but duller in the female. The head, neck, and back are black; the lower back and under parts are rich orange. The tail is orange and black. The bird is almost wholly limited to roadsides, villages, and parks, where it builds substantial hanging nests from the branches of elms and maples. It feeds mainly on caterpillars but eats other insects, now and then taking cherries. It is a welcome summer resident in the northern states.

Robins are rather large birds, ten inches in length, and rated as summer residents in the north. A few remain over the winter in favorable locations. In the male the top of the head is black. The back and tail are dark, and the breast of the characteristic dull reddish color. The females are of lighter color. Robins are found widely scattered in yards and orchards, along the roadside, in the parks, and in second-growth woods. Usually two broods are raised each season. They feed upon caterpillars, crickets, and other insects. They also eat earthworms. In some regions they are unpopular because they eat the smaller fruits, but this damage they more than pay for by destroying insects.

The *house (English) sparrow* is an imported product, like its European cousin, the starling. It was brought over from England about 1851 for the purpose of destroying certain insects, and has



FIGURE 159. A CATBIRD

He is scolding another catbird for feeding at the same place. Why is he called a catbird?

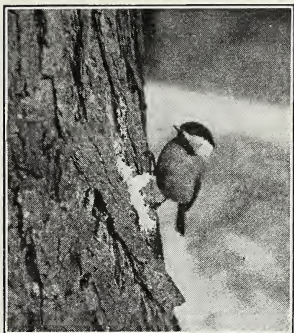


FIGURE 160. A CHICKADEE

What is the song of this bird? Can the bird whistle?



FIGURE 161. A BALTIMORE ORIOLE
AND HIS NEST

This nest is woven and will stay together for years. Why was the name Baltimore used in this bird's name?



FIGURE 162. A ROBIN AND HER NEST

This robin has built her nest in a grapevine. Is the robin helpful or harmful?

now spread to the Pacific coast. There is reason to believe that in time this bird will become a valuable addition to our bird life. It eats many weed seeds and destroys such insects as cutworms, tussock moths, some weevils, cabbage worms, and white grubs. The male has a gray crown.



FIGURE 163. MALE HOUSE SPARROW
AT A FEEDING STATION

Is the number of house sparrows
increasing in your vicinity?

Its back is streaked with black and chestnut. A part of the throat and breast is black; the under parts are whitish. The bird is a little more than six inches long. The chief fault found with the English sparrow is that it uses the nesting sites of more desirable birds and so drives them away.

The *downy woodpecker* is the best known and smallest of all woodpeckers in the United States. The principal markings are in black and white. The adult male has a scarlet band on the nape of the neck but the female lacks this

mark. The under parts are white. There is a white stripe above the eye and another below it. In the winter season the downy woodpecker frequents our orchards and yards, cleaning the trees of insects. He is also often found in the woods. Being a permanent resident, he renders a 365-days-a-year service. Every day he must procure food enough to support his active body and by doing so he renders an important service to us. Some one has estimated that each of these birds is worth \$10, measured by the good it does.

The *song sparrow* is a permanent resident in the northern states and is widely distributed in North America, showing great variation in color and size throughout the continent. It is usually a little more than six inches long and is a valuable bird because it destroys weed seeds and various insects. It keeps to the lower levels and frequents brush lands, hedges, and marshes. Occasionally it nests in holes of trees. More frequently, however,



REDHEADED WOODPECKER.

Courtesy Dr. George S. Britten.

This photograph shows how the tail is used as a brace and how the toes are opposite so as to grip the bark of the tree. These are adaptations not seen in the house sparrow, for example. Do you see any other adaptation?

it nests in the grass or shrubs along ravines, brooks, hedgerows, and open fields. It is generally gray and brown in color. Its breast has wedge-shaped streaks of black and brown with a large blotch in the center.

The *barn swallow* is nearly seven inches long. Its food is exclusively flying insects which it gets close to the ground. Unlike other fliers it seems to skim the ponds and roadways for its main supply of food. It is known to feed on grasshoppers, flies, gnats, and mosquitoes. The lower parts are chestnut and the upper part is steel blue. The tail is deeply forked. This is a summer resident and its stay in the north is brief. The nest, which is made of mud and lined with feathers, is usually placed on the rafters of old barns, sheds, or granaries. (Figure 175.)

The *flicker* is a large woodpecker about twelve inches long and is classed as a summer resident in the north. Equally at home in the woods or on the lawns, it has come to have a wide circle of acquaintances. Its colors are striking. There are a scarlet band across its neck and a black crescent

on its breast. The under parts are white, thickly spotted with black, and the upper parts are gray, barred with black. Its food consists largely of ants, but it feeds also on wood borers, like other woodpeckers. As many as 3000 ants have been found in the stomach of one flicker.

The *goldfinch* is a permanent resident but is seldom seen in the winter. The bird is about five inches long and its striking colors of gold and black make the male conspicuous as he feeds in gardens and lawns. The brilliant dress of summer is lost in the winter time and the duller colors that succeed it make the bird less easily recognized. Another reason for its being seldom seen

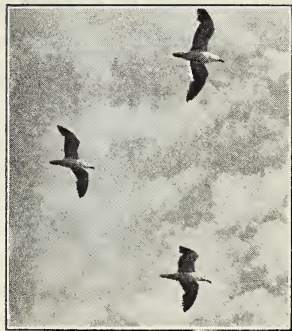


FIGURE 164. A FLICKER

Flickers have long strong beaks.
How do they use them?

in the winter is that it goes in flocks and keeps to the swamps and woodlands. Nest building is delayed until June or July in the north. The principal foods of goldfinches are seeds of thistles, dandelions, and wild sunflowers. They also eat the seeds of cultivated sunflowers.

The *phæbe* is due in the northern states when the pussywillows show their fuzzy blossoms. This summer resident is dull-colored and its note is all that gives it fame. The colors are grayish brown above and white or yellowish below. It bears distinct wing bars. Now and then conservative individuals build nests on ledges and overhanging banks but for the most part their



Ewing Galloway

FIGURE 165. GULLS IN FLIGHT

nests are built on man-made structures such as houses, barns, sheds, bridges, trestles, and viaducts. The *phœbe* is a fly catcher and for this reason man must encourage its presence. Among the insects it catches may be mentioned the click beetles, weevils, and numerous kinds of flies and moths. The nests are frequently overrun with lice to such an extent that the young are killed.

The *herring gull* is aquatic, nesting on islands and the shore of the mainland, and getting its food largely from the water. Our inland streams and lakes are frequented in certain seasons by these birds. As its name indicates, it feeds on fish, but it is not limited to that diet. Gulls are scavengers and they are found in large numbers near garbage dumps. In the lower part of New York harbor, gulls follow the scows which are carrying garbage. Mr. Frank M. Chapman estimates the number he saw here at one time as three hundred thousand. The *herring gull* is twenty-four inches long. The colors of the male in summer are deep pearl gray and white with spots of black. In winter, the male has many spots of gray.

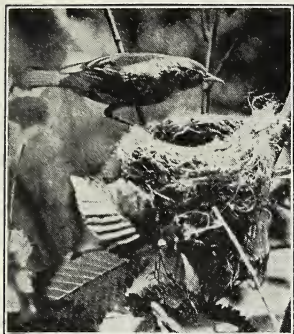


FIGURE 166. A YELLOW WARBLER
Where does the yellow warbler pass
the winter?



FIGURE 167. A PHOEBE AT HER NEST
What is the food of the phoebe?
Where does she usually build her
nest?

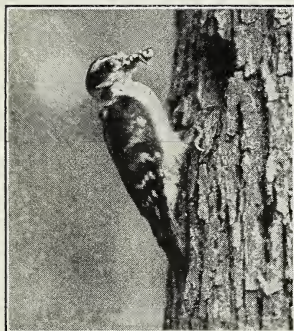


FIGURE 168. A DOWNY WOOD-
PECKER AT THE ENTRANCE TO HER NEST
IN A TREE

This woodpecker digs out the wood
with her beak. Are there eggs or
young in the nest?



FIGURE 169. A SCREECH OWL AT-
TRACTED BY A CAGE OF MICE

The owl took his own picture by
means of an electric perch and flash-
light powder.

The *screech owl* is one of our smallest owls, having a length of only nine and one-half inches. The bird has two color phases, a rufous and a gray. In the former phase the colors are rufous above with streaks of black and white below. In the gray phase the rufous is replaced by gray. These color phases do not depend on age, sex, or season. Screech owls are permanent residents and mostly beneficial, as they feed largely on mice and insects. They sometimes eat earthworms. During the day they rest in hollow trees, conifers, old buildings, and caves. They also nest in hollow trees or bird boxes.

The *yellow warbler* is one of our smallest warblers and measures about five inches in length. The male is greenish yellow above and bright yellow beneath. The lower parts are streaked with rufous. It courts man's company and keeps well to the yards, gardens, and roadsides. It is a summer resident. The nest is compactly built of fine grass and fibers and lined with plant down or hair. This bird is frequently victimized by the parasitic cowbird. The eggs of the cowbird are sometimes buried beneath another nest which the yellow warbler builds in an effort to avoid hatching a cowbird's egg.

Wrens, of which there are some 150 kinds known to science, are found mostly in the tropics, only about twelve species occurring in the United States. They frequent stubby growths and bushes. The house wren is 5 inches long. The upper part is brownish, the back generally has indistinct bars, the wings and tail are finely barred, and the under parts of the body are whitish with numerous blackish bars on the sides. It breeds as far north as Manitoba and winters in the south. In our climate wrens are nearly always found around dwellings; when they become attached to a nest, they return year after year. They are among our friendliest birds.

143. Migration of Birds. — Many strange ideas have been entertained about bird migration. Some thought that one kind of bird changed into another kind. In recent years more observation has been given to this subject. At the present time the movements of practically all of our birds are known. Some of the

flights that they make are almost beyond belief. For example, the golden plover nests on the shores of the Arctic Ocean and winters in Argentina, 8000 miles away. The arctic tern may travel 11,000 miles between its winter and summer homes. The black poll warbler flies 7000 miles to the place where it rears its young. The Baltimore oriole winters in Central America, while



FIGURE 170. CANADA GEESE (WILD GEESE) RESTING NEAR A FEEDING STATION
Can you find the leader?

the bobolink winters in Brazil. The red-eyed vireo and kingbird spend the winter in Bolivia, and the yellow warbler in Peru. At least one of our North American birds, the wheatear, which nests in the arctic regions, passes the winter in West Africa, migrating through the British Isles.

The recent studies of starlings are very suggestive in explaining a possible origin of the migration habit in birds. The English starlings of the northern states, after more than 30 years of residence, have finally learned to migrate. Huge flocks of these birds now go south in the fall, and return with the coming spring. They may truly be said to have been naturalized. Until recently,

through sheer ignorance, they have had to adapt themselves to a climate wholly unnatural in its severity, for at home in northern



FIGURE 171. EUROPEAN STARLING

His beak is poorly adapted to the work of breaking frozen suet, but he succeeds in getting a few crumbs and continues to visit the feeding station.

The starlings have been residents of the United States since 1890. They multiplied rapidly and drifted into the surrounding country and, as years passed, spread farther and farther into the country, until now they are common all through the East and the central states. Their first knowledge of migration, ornithologists believe, probably came from their contact with flocks of blackbirds and purple grackles, with which latter species they are confused by many people, though they are easily distinguished by their yellow bills. They mingled with

Europe the species migrates regularly to southern Europe, and even to northern Africa, it is said. Many of them managed to survive even the rigors of the New England winter, but only because they were very resourceful in snatching a living under most adverse circumstances. Some of them are still unaware of the milder climate southward, in a land where food is plenty, and persist in making their night winter quarters in the belfries of the steeples of cities and towns or more rarely in a country barn.

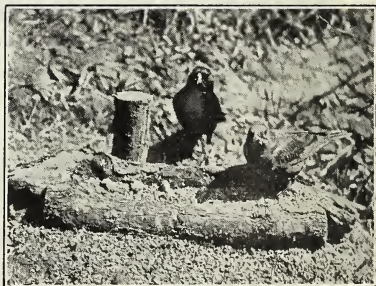


FIGURE 172. MALE (left) AND FEMALE (right)
COWBIRDS AT A FEEDING STATION

The female lays her eggs in the nests of other birds. (What is a parasite?)

flocks of these and other species, and doubtless began to drift southward with them in the fall and back again in the spring.

The long distances that birds fly in migrating, the unerring course they follow, and the regularity of their appearance — all lead us to ask: How is it done?

In theory, we assume that it must be done by other senses than those we have. They must have an unusual sense of direction and the instinct known as the homing instinct developed to a high degree.



FIGURE 173. PRAIRIE HORNED LARKS
What are the horns?

144. Methods of Attracting Birds. — For the purpose of study and appreciation, it is advantageous to bring the birds near the windows of a home where we may look upon them at odd times and study them at close range. There are several ways of getting the birds to come near a building. A common method is to feed them. Food such as suet, bread crumbs, hemp, canary seed, sunflower seeds, and raisins are attractive to birds. They should be so placed that cats cannot strike down the birds while they are feeding. Unless some care is exercised in selecting these feeding places, the birds will be lured into the claws of the ever-waiting cat.

Suet may be attached by a wire loop on the side of a tree trunk three or four feet from the ground. Bird seed and crumbs may be placed on the ground, but a better method is to put the seeds and crumbs in a box with a wide entrance and a cover a few inches above to keep out the snow. This box should be placed on a post or on the side of a tree trunk a few feet from the ground.

Food placed on the ground is likely to be eaten by stray dogs or cats, and in the winter time it will be buried by the snow. Sunflower heads may be hung from the sides of a tree trunk or put on the end of a post.

During the winter the chickadee, white-breasted nuthatch, downy woodpecker, hairy woodpecker, red-headed woodpecker, brown creeper, flicker, and many other birds may come to the

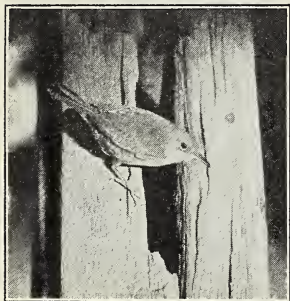


FIGURE 174. THE HOUSE WREN AT THE ENTRANCE TO HER NEST

The house wren comes readily to nesting boxes put up for her. If the hole is no larger than a twenty-five cent piece, no other birds will enter.

those put up in the trees. Poles and posts may be covered with tin or sheet iron to keep the cat from climbing them.

The size of the opening and the inside space determine what birds will be likely to use the boxes. The table at the end of this chapter (see page 186) will give an idea of the size of the opening and cavity and the locations that are considered proper for some of our town birds.

Bird Baths. — During the dry weather of July and August, the supply of water is greatly reduced. Sometimes the water that is available is in a place where the birds have no chance of escaping a cat that is lying in wait for them. A shallow plate of

suet. Juncos, tree sparrows, house sparrows, pheasants, crossbills, evening grosbeaks, song sparrows, and prairie horned larks will come to the bird seed and crumbs. Sunflower seeds will attract chickadees, house sparrows, crossbills, goldfinches, and evening grosbeaks.

Nesting Boxes. — The putting up of nesting boxes in the yards is another way of attracting birds. But they must be guarded against cats. Cats will climb to the boxes if they can and strike the birds as they leave the nest. Boxes put up on the ends of posts and away from trees seem to be preferred to

water placed on a stump or post in the shade is frequently used by the birds. Sometimes a dozen or more kinds of birds will come to these drinking places. At one such bath the following birds came during one summer: robin, oriole, catbird, yellow warbler, song sparrow, pewee (to catch insects at the water), red-headed woodpecker, black-throated blue warbler, and goldfinch. Birds will bathe in drinking fountains if they are shallow enough to allow them to wade.

145. Public Museums. — As man came to occupy the land, the forests were cleared away and the ground was used to produce food. This tended to drive the wild animals into more inaccessible places, where they were free to live. But for this many might have become extinct. Some, like the bison and the brook trout, could not get away, and were rapidly dying out when the government took measures for their conservation.

With the advance of civilization and the growing scarcity of wild life, it has become more and more difficult to study these animals at first hand. Realizing the importance of such study, different communities have founded great public museums, in which are preserved skeletons and stuffed specimens of wild animals, so arranged that they can be carefully and systematically examined.

The government has reservations where wild life is protected, but for purposes of study these are not so suitable as the museums. Every pupil who can should go to a museum, zoölogical park, or

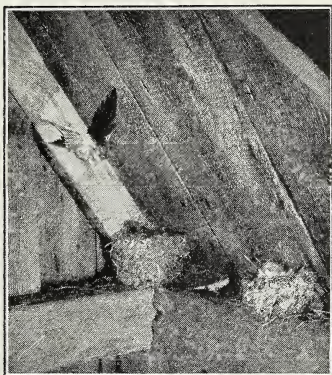


FIGURE 175. A HABITAT GROUP OF BARN SWALLOWS AT THE NATURAL HISTORY MUSEUM

How do these specimens help in the study of biology?

botanical garden in connection with different parts of his biology course, in order to study the actual specimens of which there are pictures and drawings in this book.

SIZE OF NESTING BOXES

BIRD	DIAMETER OF OPENING	SIZE OF CAVITY	LOCATION
Chickadee	1 $\frac{1}{8}$ "	4 × 4	In protected spots
House wren	1 $\frac{1}{8}$ "	4 × 4	Trees and arbors
Nuthatch	1 $\frac{1}{4}$ "	5 × 6	On buildings or trees
Bluebird	1 $\frac{1}{4}$ "	5 × 6	On buildings or trees
Tree-swallows	1 $\frac{1}{4}$ "	5 × 6	In trees near ponds
Red-headed woodpecker .	2 $\frac{1}{2}$ "	6 × 7	On posts or trees
Flicker	3"	6 × 8	On posts or trees
Wood-duck	6"	10 × 18	Trees or stumps

SUMMARY

Birds represent a highly specialized group of vertebrates that are easily recognized as they are the only ones that have feathers. They far surpass the amphibians and reptiles combined in the number of different species so that even beginning students must know something of the classification of birds.

Birds are classified according to their structure and also according to their migratory and nesting habits. Birds are peculiarly adapted to the work they have to do. Their wings, legs, feet, and beaks vary according to their mode of life and the kinds of food they live on. The lightness of their hollow bones is a help to them in flying. Their body temperature is high and they digest food quickly; this gives them much energy for their active lives.

Birds are of enormous economic value, chiefly because of the large number of insects they destroy. For this reason the government protects them and they are also taken care of by private organizations and individuals. Domestic birds supply us with food.

Birds migrate with the seasons, sometimes going thousands of miles. Some winter in northern United States, spending the summer still farther north. Others go north in the summer and south for the winter. It is pleasant to get them to stay with us, for they are delightful companions. This may be done chiefly by feeding, and also by putting up nesting boxes and arranging bird baths. Bird study is a fascinating subject and a great deal of pleasure may be derived from the ability to recognize common birds.

QUESTIONS

In what ways are birds classified? How are they economically important to man? In what ways and by what agencies are they protected? How many common birds can you recognize by sight? Name them. What are the different adaptations of birds? For what purposes is the beak used? the claw? the wings of a penguin? What are the advantages and disadvantages of the plumage of the average male bird? of the female? Why do birds migrate? What birds go north in summer? Which ones go south in winter? Do you know any that spend the year in your part of the country? What summer bird do you usually see earliest in the spring? What are the best ways of attracting birds? Have you ever tried any of these ways? Have the European starlings reached your town?

SPECIAL TOPICS FOR DISCUSSION

1. Compare the helpful work of the crow with its harmful work.
2. What birds are most readily attracted to feeding stations?
3. What food that can be used in feeding stations will bring the greatest variety of birds?
4. What birds in your vicinity are increasing in number and what birds are decreasing in number?
5. What birds have been introduced from abroad and with what success?
6. Show how more birds of the right kind would decrease the number of insects.
7. Make a list of the first ten birds to arrive in your town and compare it with a list of the last ten to leave for the south.
8. Are hawks in your vicinity generally harmful or helpful to agriculture?
9. What men now living are aiding in bird protection?
10. Make a list of organizations that try to protect birds.

REFERENCES

- Allen, *The Book of Bird Life*, D. Van Nostrand and Company
Allen, Fuertes, and Pirnie, *Laboratory Notebook for Intensive Bird Study*,
Comstock Publishing Company
Bailey, *Birds of New Mexico* (out of print)
Baynes, *Wild Bird Guests*, E. P. Dutton and Company
Chapman, *Autobiography of a Bird Lover*, D. Appleton and Company
Chapman, *Handbook of Birds of Eastern North America*, D. Appleton and
Company
Forbush, *Useful Birds and Their Protection* (out of print)
Hoffman, *Birds of the Pacific Coast* (out of print)
Thomson, *The Biology of Birds*, The Macmillan Company

CHAPTER XV

MAMMALS, THE RULERS OF THE EARTH

A righteous man regardeth the life of his beast.

— PROVERBS XII, 10

146. Characteristics of Mammals. — Mammals are characterized by having hair. They have ruled the animal world ever since the huge reptiles became extinct, thousands of years ago.



Strohmeyer

FIGURE 176. GERMAN SHEPHERD DOG AND PUPPIES

This place they have maintained because they have the best developed brains of all animals. They are warm-blooded (the body temperature remaining the same in winter and in summer), breathe by means of lungs, give birth directly to young, and are provided with milk glands to suckle their young. A muscular wall (diaphragm) subdivides the body cavity into two parts. The

anterior contains the four-chambered heart and the lungs; the posterior contains the stomach, intestine, liver, kidneys, and reproductive organs. At birth the young resemble the parents in having the same parts.

All the animals that you have studied in this course were able to live because they secured food which nourished their bodies, exercised the function of respiration, excreted waste, were adapted to their environment, and reproduced their kind. You have become so familiar with these life functions that it is necessary only to say that they apply in the same way to mammals.

147. Classification of Mammals. — There are some 800 different kinds of mammals in New York State alone, but even this great number does not represent all of the larger groups. The following classification of mammals is for reference and need not be memorized.

1. Mammals with flexible fingers (*Primates*): lemur, monkey, ape, man.

2. Hoofed mammals (*Ungulata*): cattle, horse, deer, giraffe, pig, rhinoceros.

3. Flesh-eating mammals (*Carnivora*): cat, dog, civet, mink, raccoon, fox, bear, seal, lion, wolf.

4. Gnawing mammals (*Rodentia*): rabbit, squirrel, beaver, rat, porcupine, mouse.

5. Pouched mammals (*Marsupialia*): kangaroo, opossum.

6. Insect-eating mammals (*Insectivora*): hedgehog, mole, shrew.

7. Toothless mammals (*Edentata*): sloth, anteater, ant bear.

8. Trunk mammals (*Proboscidea*): elephant.

9. Flying mammals (*Chiroptera*): bat.

10. Mammals adapted to marine life (*Cetacea*): whale.

148. Carnivora. — The term Carnivora means “flesh-eating”; in this order of mammals we find the canine teeth (Figure 427) well developed and the jaws strong. There are the aquatic carnivores, sea lion, walrus, seal; and the land carnivores, which in turn are divided into three well-known groups: (1) bear and raccoon which walk flat-footed; (2) wolf, coyote, lion, tiger, hyena,

cat, dog, etc., which walk on their toes only; (3) weasel, otter, skunk, and mink that walk partly on the toes.

149. Skunks and Weasels. — The skunk is the commonest of the wild, flesh-eating animals. Close relatives are the minks and weasels. All of these animals, especially the skunk, are capable of discharging a strong and almost suffocating odor when annoyed or angry. This offensive odor is manufactured in glands located near the tail and is an adaptation that has had a decided influence

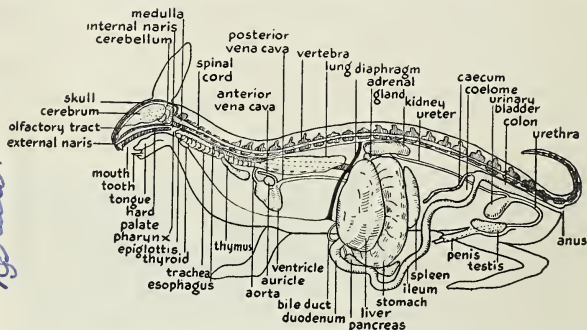


FIGURE 177. DIAGRAM OF ORGANS OF A MAMMAL

on the habits of the skunk. The skunk is no longer required to be alert to escape its enemies and so has become fat and lazy. Its muscles are soft, and rapid exertion exhausts it sooner than any other member of this group.

The food of the skunk consists of grasshoppers, crickets, frogs, snakes, rabbits, eggs, the young of birds, and field mice. It is only occasionally that a hen is captured, and the general habits of this animal are beneficial. Skunks hibernate for short periods in the winter in the holes of other animals. They usually come out in February, and at this time their food consists of mice and moles.

By May the young are able to begin foraging for their own food, and it is not unusual in the early evening to see the mother and her brood slowly wandering about as they capture insects.



RED FOXES.

The red fox is one of the few wild animals that have survived as man has come to occupy the land. The secret of his success lies in his skill in outwitting man and dogs. This skill and his remarkable swiftness in running aid him also in capturing his food.

Skunk fur is made up chiefly in neck pieces and coat trimmings, and the demand for it has become so great that regular skunk farms are conducted at a profit, due to the increasing demand for fine furs.

Closely related to the skunks are the weasels, which are very destructive to birds, rabbits, squirrels, and poultry. Their thin, muscular bodies enable them to move with great rapidity and their endurance carries them many miles in a single night. It is interesting to note the difference in habits between skunks and weasels. Weasels should be killed whenever possible.

150. Rodents. — The rodents are the gnawing mammals which have the incisor teeth chisel-shaped and much enlarged. These gnawing teeth of the rodents do not wear out because they keep growing, and they also keep sharp because the front edge is harder than the back. Rodents lack the canine teeth of the Carnivora. It is only necessary to name the more common members of this order to realize how very destructive the rodents are, for here are included the rat, mouse, rabbit, porcupine, chipmunk, squirrel, muskrat, beaver, and woodchuck.

151. The Beaver. — Its social habits and architectural ability make the beaver one of our most interesting mammals. The demand for its fur has led to its extermination in many parts of the country. In the Adirondacks beavers were trapped and hunted with such vigor that for a few years previous to 1905 none was to be found. In 1905 several pairs were obtained from Yellowstone National Park and liberated near the old beaver haunts in the Adirondacks, and at the same time laws were passed protecting



FIGURE 178. DEER MOUSE

This nocturnal rodent, by nibbling the bait, set off a flashlight, opened the camera shutter, and rang a bell in the owner's home a half mile away.

them. Now they are numerous throughout the Adirondacks wherever natural conditions are favorable. They live on the bark and shoots of tender young trees.

Beavers live in colonies and work industriously in building dams and houses. Some damage is done by their cutting trees and



FIGURE 179. A BEAVER FAMILY HARD AT WORK
How many different things are these beavers doing?

damming up streams, but the great popular interest in beavers and their works and the value of their fur more than outweigh the little harm they do.

152, The Rat, the Worst Mammalian Pest. — Early in our life as a nation the black rat was introduced from Norway. For a time it spread rapidly and soon became a nuisance. Some time later the brown rat came from Europe, escaping from the boats. This animal exhibited from the first great versatility in its habits and food. It was so much more pugnacious than the black rat that it was but a few years before the earlier immigrant was almost completely exterminated by this later arrival.

The brown rat causes damage to cereals and grains estimated at more than \$200,000,000 annually in the United States. In this

connection you should read *The Brown Rat in the United States*, by David Lantz, Bulletin No. 33, Biological Survey, United States Department of Agriculture.

The rat is the active agent in the spread of the dreaded disease known as bubonic plague, which has an almost world-wide distribution. During the twenty-year period ending in 1923, this disease killed over 11,000,000 people in India alone. Consult Public Health Bulletin No. 180, *The Rat: Arguments for Its Elimination and Methods of Destruction*.

153. Rabbits. — Rabbits are the most widely hunted of all wild animals. Man, bird, and beast hunt them.

Rabbits are serious pests in orchards and tree plantations. They also do considerable damage to garden truck and other farm products.

The cottontail rabbit breeds several times each year during the warmer months, with litters averaging five or six young. The nest is placed in a hollow or depression in the ground and is composed of dead grass lined with fur which the mother pulls from her own body. These animals breed so fast that, despite their many enemies who hunt them for food, they may become so numerous as to constitute a serious hindrance to food production.

The carnivorous birds and mammals are usually successful in keeping rabbits from becoming a menace. Hawks, owls, and eagles are the chief birds that destroy them, while foxes, minks, weasels, skunks, dogs, and cats are the mammals that prey upon rabbits.



FIGURE 180. A COTTONTAIL RABBIT

In 1919 scientists began seriously to investigate rabbit fever, a disease that may be carried by bites of deer flies and ticks. What precautions should cooks and hunters take against this disease?

154. Ungulates. — This important group of mammals includes our most useful domestic animals. They are called the hoofed mammals and are divided into two great subdivisions:

1. Odd-toed, as the horse, tapir, rhinoceros.

2. Even-toed.

(a) Those that do not chew the cud, as the pig and hippopotamus.

(b) Those that do chew the cud, as the cow, sheep, and deer.

The expression "chew the cud" refers to the habit of hastily swallowing food which is later forced again into the mouth and then thoroughly chewed. Such animals are known as ruminants and have a specially modified stomach.

155. Horses and Mules. — The horse has been associated with man since the Stone Age, and next to the cow has been his most useful animal. It has been suggested that man first hunted horses for food, then drove them, and finally used them for riding and as beasts of burden. The fine animals which we see today have gradually developed over a long period of time from a small animal about the size of a fox terrier. The ancient horse had four toes and the remains of a fifth in the front foot, while the hind foot had three toes and the remains of a fourth. The horse and the deer, which also has many stages preserved in the rocks, afford examples of the manner in which some of our present animals have developed.

The domesticated horses were developed in the Old World. In the warmer regions, where food was plentiful, the largest horses developed; while in the north, where food was less abundant and conditions more severe, the Shetland pony appeared.

The mule, offspring of horse and donkey, has been known for many centuries. Even in the days of ancient Greece and Rome mules were used in agriculture. They are more enduring and more patient, live longer, and are surer-footed than horses, and are widely used.

156. Pigs. — The pig has been developed from the wild boar of the Old World. Meat is obtained more cheaply from the pig

than from any other animals, because it adds more weight for a certain amount of food than either sheep or cattle and does it in a shorter time.

157. The Cow. — Cattle are descended from the wild ox of Europe and Asia, and practically all our popular breeds have been developed in the Old World, mainly in the British Isles.

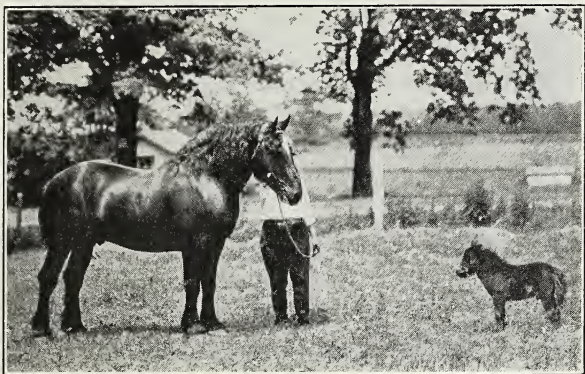


FIGURE 181. PERCHERON STALLION AND SHETLAND COLT

Strohmeyer

At the left is shown one of the largest breed of horses and at the right one of the smallest breed of ponies.

There are two chief types of cattle: the beef type used for food, and the dairy type most valuable for the milk, butter, and cheese that they produce. The beef type is characterized by "blocky" bodies, a form which yields the greatest quantity of meat. The beef cow is not expected to produce much milk. The dairy type presents a different appearance from the beef type, having a bony, angular body and a very large udder. The island breeds, Jersey and Guernsey, are famous for the production of butter fat rather than for the quantity of milk. The Ayrshires, a Scotch breed, are known for the superiority of their milk for cheese, for the large proportion of butter fat, and for the fact that they yield more beef than any other dairy breed. Dutch cattle, the Holstein-

Friesian breed, are famous for the quantity of milk that they produce. The milk is also superior for cheese-making and, on account of the large quantity they produce, these cattle rank foremost in supplying cities with milk. Oxen of this breed grow to large size and are much prized as work animals.

*Strohmeyer*

FIGURE 182. A COW AND HER TWINS

In what ways is this cow valuable or of use to man?

158. Sheep and Goats. — The shepherd has been a famous character in literature. Sheep in the Old World were possibly the first mammals domesticated by man. They thrive in nearly all climates and can find food where other mammals can scarcely live. Sheep furnish wool and meat. There are three classes, based on the quality of the wool. These are the fine-wool breeds like the merino, which had its origin in Spain, whence they have been carried to all countries where sheep raising is an important industry; the medium-wool breeds like the Shropshire; and the long-wool breeds like the Leicester, both of which are English breeds. The fine-wool breed is raised principally for the wool, the meat value being a secondary consideration, while the medium-wool breeds are raised principally for meat, and the wool is a

secondary consideration ; in the long-wool breeds the mutton and the wool are of equal importance.



FIGURE 183. A FLOCK OF SHROPSHIRE SHEEP

Strohmeyer

Closely related to sheep are goats, which are the main supply of milk and meat in the island of Malta, in Switzerland, southern Italy, and Asia Minor.

159. Primates. — The Primates are a distinct group of mammals with the brain especially well developed. This is the main reason why we regard the animals in this group as the highest mammals. Lemurs and monkeys live chiefly in trees, while most apes seldom leave the ground. All have nails in place of claws on the fingers and toes. The body is completely hairy. The fore feet are grasping hands as a rule, and the hind feet walking as well as grasping appendages.

160. Chiroptera. — Bats, the shadowy creatures that fly about at night, differ from all other mammals. They have the bones of the fingers greatly elongated, but there are no more joints or bones in each finger than in your own hand. Over these



FIGURE 184. ARM (WING) OF BAT

Compare these fingers with yours.

greatly lengthened fingers is stretched a thin, rubbery wing-membrane which is double in thickness. It is also attached to the side of the body, hind legs, and tail. In this membrane are



FIGURE 185. A BAT SLEEPING WHILE HANGING FROM A BRANCH

found special sense organs that enable the bats to detect objects as they fly rapidly in the dim evening light. When their eyes are covered with wax so that they cannot see and they are set free, they fly about freely, never touching objects, even avoiding and passing between silken threads. Their sense organs consist of numerous hairs supplied with nerves. These hairs are stimulated by the rebound of the air from the objects which the bat is approaching.

A bat's food consists of insects which are captured both with the mouth and the wing-membrane where it is attached to the body.

The feeding time varies with the kind of bat, some seeking their food in the early evening, others early in the morning. All of the bats destroy so many insects that we regard them as highly beneficial.

The young are born in early summer and among some kinds are carried around by the mother for the first two or three weeks as she flies at night. After this they are left "hung up" in some retreat while the mother gathers food for them and herself. When the young are three months old, they are able to fly and forage for themselves.

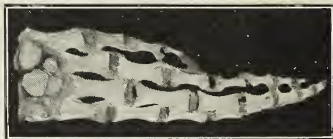


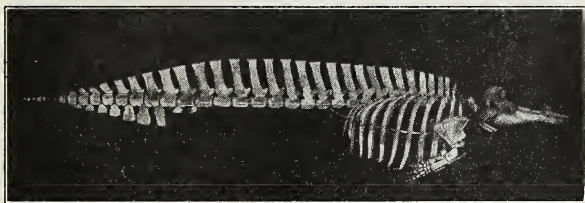
FIGURE 186. SKELETON OF WHALE'S FLIPPER, A MODIFIED HAND

161. Special Adaptations of Mammals. — Most mammals have two pairs of limbs; the fore limb may be variously modified for different uses, as for running on hard ground in animals like the horse, for tree-climbing and for food-getting in the squirrel, for burrowing in the moles, for flying in the bats, and for swimming in the seals. In all fore limbs of mammals, even those as different as the leg of the squirrel, the flipper of the whale and seal, and the wing of the bat, the arrangement of the bones is the same.



FIGURE 187. FOREARM AND HAND OF MOLE
Compare this with your hand.

The hind legs of mammals do not show so much variation as the forelegs, but in some cases, as in the whale, the hind legs have almost disappeared through disuse and there is no external evidence of them (Figure 188). Almost the reverse is true of the kangaroo, which moves by hopping on its big hind legs. Some animals, like bears, walk on the soles of their feet, and some, like cats and dogs, walk on their toes only. Animals vary in the



American Museum of Natural History

FIGURE 188. SKELETON OF WHALE

number of toes; for example, the cow walks on two toes, the horse on one toe, the hoof being a modified toenail. In such cases the other toes are entirely lacking or not perfectly developed.

The skeleton of mammals is built on a similar pattern in all cases. In the vertebral column (Figure 394) there are several

regions, such as neck, rib, back, hip, and tail. It is true that the number of the separate vertebræ in the neck region is the same in the dog, horse, mouse, giraffe, bat, man, etc., but the neck region is not of the same length. Each of these vertebræ in the

neck of the giraffe is very large, and this adaptation helps him in securing his food, which consists of the leaves of trees (Figure 190).

Some strange modifications, the pouch of the kangaroo and the trunk of the elephant, should also be mentioned. The kangaroo is one of the simpler animals. The young are helpless at birth and are placed by the mother in a special pouch in which they are carried around (Figure 190) until they are able to take care of themselves. The milk glands are located in the pouch so that the young are easily nourished and protected. The trunk of



FIGURE 189. FLYING SQUIRREL

How does it fly? Is this a correct name?

the elephant is composed of the nostrils and upper lip drawn out into a long muscular organ (Figure 191), and is used in bringing food to the mouth. The web of the flying squirrel is another strange adaptation which enables it to sail more easily through the air.

Adaptations for Protection. — Mammals are found all over the earth, living in the frozen north and the humid tropics or roving over plains and mountains. Everywhere they show adaptations in habits and form.

The color of the white polar bear and arctic fox renders them inconspicuous against the ice and snow. Deer are among our

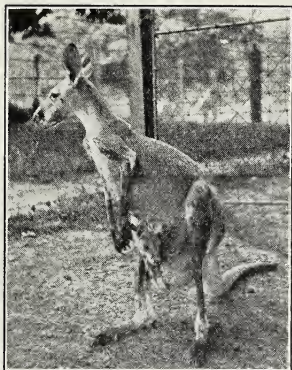
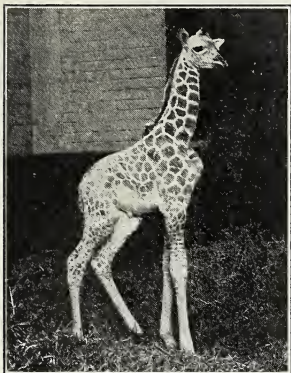


FIGURE 190. A GIRAFFE AND A KANGAROO

The giraffe, at the left, is five days old.

Notice how the kangaroo at the right carries its young in a pouch. Its tail is used as a prop when resting.



FIGURE 191. AN ELEPHANT AT WORK

Ewing Galloway

This elephant is handling teakwood logs in a lumber yard. What kind of adaptation is shown?

swiftest runners and the possession of such speed helps them to escape when they are chased. In marked contrast to the habit of the deer when it is in danger is that of the opossum (Figure 192), which often rolls up into a ball and feigns death. After

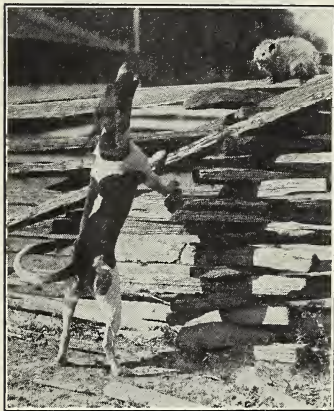


FIGURE 192. DOG AND OPOSSUM

In this picture, which is bluffing, the dog or the opossum?

the animal which has been annoying the opossum goes away, it deliberately and slowly begins to move.

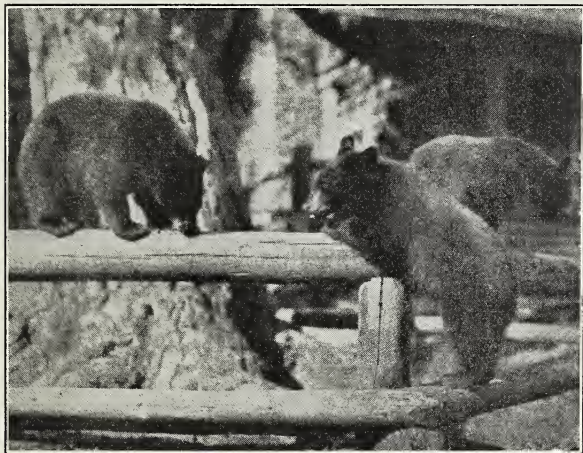
Whales are water mammals that have lost most of their protective coat of hair but have developed instead a thick layer of protective fat beneath the skin. This is whale blubber. The porcupine has its hair enlarged and stiffened into sharp spines. These special hairs protect the porcupine effectively from lynxes and wild cats. Such spiny hairs are in marked contrast to the protective coat of wool of sheep, which also is modified hair.

There are many more examples of protective adaptation in mammals. How many can you name?

162. Humane Methods of Hunting and Protection. — Wild animals are valuable for the food and especially for the fur they furnish to man. The early stories of the Hudson's Bay Company tell us of the men who set their traps over a large area, visiting them possibly but once a week. Animals that were caught in these strong steel traps were unable to escape, and there was a long period of suffering that should have been avoided. This can be done by requiring trappers to visit their traps often in cases where traps are the only means of capturing the animal. In some instances the trap can be set under water, and the animal is drowned almost as soon as it is captured. This is a humane method.

From early times it has been customary to make pitfalls into which animals fall and from which they cannot escape. Here there is no suffering, but such traps require constant attention, and so are frowned upon by trappers.

The S. P. C. A. — The Society for the Prevention of Cruelty to Animals was organized primarily to protect domestic animals: to keep horses from being beaten or overloaded, and to furnish



© J. E. Haynes, St. Paul

FIGURE 193. BEAR ACROBATS AT YELLOWSTONE PARK

Would you like one of these as a pet? What would you feed him?

proper care to neglected cats and dogs. But it also provides for the humane killing of strayed or old animals, and takes over the care of pet animals while their owners are away.

Mammal Sanctuaries. — Yellowstone National Park in the state of Wyoming is the best-known sanctuary in the United States for large mammals. Here the bison, moose, elk, mule deer, white-tailed deer, and black and grizzly bears are protected during the entire year. Even such predatory mammals as the timber wolf, coyote, and mountain lion are partially protected

in this park. The number killed is determined by the destructiveness of the animal to the other animals in the park. As soon as the predatory animals become too numerous, a few are killed in order to keep them from becoming a serious menace. This is one of the first instances in our country where destructive



FIGURE 194. SEALS ON ONE OF THE PRIBILOF ISLANDS, ALASKA

The seals come here every year, where they are easily caught and killed. Why are they valuable?

animals are being preserved in a wild state for educational purposes. The Bureau of Biological Survey administers seventy-six game and bird reservations.

163. Economic Importance of Mammals. — Man finds some animals helpful, some harmful, and some neither. The domesticated mammals, especially the horse, cow, sheep, goat, and pig, are of the greatest use to man in this part of the world. In cold regions, reindeer are the main source of food and clothing, and are also used as beasts of burden. In desert regions, the camel is the most useful, and in hot regions elephants are of great value as beasts of burden. It is not too much to say that these domesticated mammals are almost indispensable to man's existence. Certainly without them our ways of living would undergo vast changes. Dogs and cats have long been man's companions, and

the former were much used in olden days to hunt down and kill man's animal enemies as well as to protect his livestock from their ravages. Of the wild mammals, seals and walruses, which live in the water, furnish food, fur, and leather. The whale furnishes whalebone and oil.

Man is profiting by learning the habits of other mammals; for example, we build roosts in the vicinity of swamps and marshes to furnish shelter for bats by day. At night the bats fly about, catching the insects which annoy man and animals. Economic experts in the Biological Survey in 1928 estimated that rodents alone, such as mice, rats, prairie dogs, gophers, and jack rabbits, eat or otherwise cause the loss each year of crops worth approximately \$500,000,000.

Rats and mice consume much food and destroy much that they do not eat, besides carrying diseases. Red squirrels damage beds and furniture if they gain access to the house, and out of doors they destroy the eggs and young of birds and the seeds of evergreen trees.

Rats, mice, and guinea pigs have proved of great use in laboratories where the causes and effects of diseases are studied. Their reaction to diphtheria, tuberculosis, cancer, and other diseases is similar to that of man. As a result of these experiments physicians have learned much that helps in the treatment of disease in man.

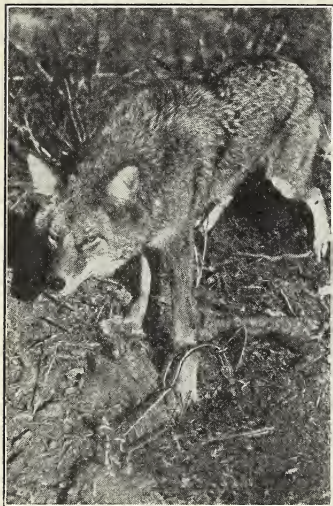
The following form should be copied. Begin entering your observations now on the copy, and keep the report up to date during the year.

REPORT ON MAMMALS

TO BE FILLED OUT FIRST FROM GENERAL KNOWLEDGE, LATER EXTENDED
BY TRIPS TO FIELDS, WOODS, OR PARKS

KINDS	WHERE FOUND	FOOD	KIND OF FOOD	LIFE IN WINTER	LIFE IN SUMMER	BENEFI- CIAL	HARMFUL

164. Necessary Destruction of Mammals. — During the year 1922, the United States Bureau of the Biological Survey employed more than 250 expert hunters who killed, trapped, and poisoned approximately 80,000 of the dangerous and predatory mammals. The grazing areas for horses, cattle, sheep, and goats are in the western mountain and prairie states, where these mammals are numerous.



Courtesy Bureau of Biological Survey

FIGURE 195. A TRAPPED COYOTE

Why are man and the coyote such bitter enemies?

It is interesting to report that in 1928 the state and national organizations combined employed more than 400 expert hunters who did not kill nearly so many of these predatory mammals as were taken in 1922 because these animals are rapidly being exterminated. A new discovery has helped the capture of such fierce enemies of domestic stock. A man was walking about in the National Zoo with a sprig of catnip in his pocket and observed that various dangerous animals in

their cages exhibited very friendly interest in him. Experiments were made and now "cat" animals are baited by catnip oil and much more safely captured.

165. Conservation of Useful Mammals. — With the steady growth of population, more and more wild animals have been killed to supply the increased demand for food and clothing. In fact, so great has been the slaughter of the most valuable ones that laws have been passed to protect them from total extinction. Some of these laws make it illegal to kill certain kinds of mammals

at any time of the year; others protect them only while they are rearing their young. In the first class in New York State, we have the elk and beaver, and in the second the deer, fox, and raccoon. The laws protecting mammals are not uniform throughout the United States.

These regulations were fairly satisfactory until fashion decreed that furs should be worn summer and winter. In order to supply this whim more than one hundred million hides were sold in the markets of the United States during the years 1919 to 1921, inclusive. This was an enormous increase in the use of the skins of mammals.

Many of our common mammals were not extensively killed for their fur until 1919. During the three years for which there is a record, over fourteen million muskrats were sold as Hudson seal, nearly twenty-four million insect-eating moles, and over thirteen million hides of the American and Australian opossums were marketed. These are but four of the nineteen kinds of fur bearers recently introduced by the fur trade to replace the original fur bearers whose supply is diminishing. The entire world is being searched to meet this abnormal demand. Many regions have no protective laws, so that the extinction of the fur-bearing animals inhabiting them is imminent, unless we are willing to forego the gratification of our desire to wear furs as ornaments.

166. Other Products Furnished by Mammals. — Many of the animals we have just been studying supply us with food, fur, and



Ewing Galloway

FIGURE 196. A FOX FARM

Here black foxes are raised. How is this related to the conservation of animal life?

wool. But mammals also furnish us with various other things, such as leather, oil, and buttons.

Leather. — Tanning, or leather manufacture, is a very ancient art, and was practiced with considerable skill by the earliest of civilized peoples. The Babylonians and Egyptians made leather much as it is made today.

This large industry depends upon the structure of the skin in mammals, especially the arrangement of the fibers in the dermis

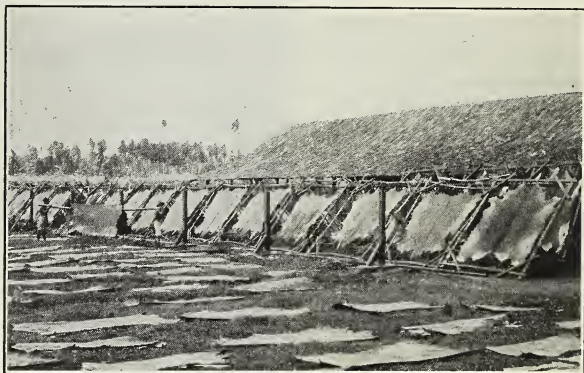


FIGURE 197. A PRIMITIVE METHOD OF TANNING

What is happening to the skins in this picture?

(the inner layer of the skin). In the skin of a fish or an alligator, the fibers of the dermis run parallel and at right angles in the several layers, while in the hairy animals these same fibers do not follow any order of arrangement. This makes an interlacing network, thus producing a strong skin which resists tearing or flaking.

Most of the leather that is used in shoes today comes from the hides of cattle. The hides must be removed with care to avoid cutting, as all such injuries destroy the fibers of the dermis. These hides are then sent to tanneries, where each is made into a certain grade of leather, such as sole leather or the leather for the

upper part of the shoe. This difference in thickness and firmness is produced largely by the method employed in tanning. When a vegetable tan is used, such as hemlock bark, oak, or sumac, sole leather results; and when a mineral tan is employed, leather suitable for the upper part of the shoe is secured.

Two common parasites, the white grub and the southern cattle tick, live in the skin of cattle and render it unfit for leather. The United States Department of Agriculture has greatly assisted cattle raisers in ridding their cattle of these destructive parasites.

Another biological factor in the production of good leather is the care that the cattle receive. If they are well fed and properly housed during the winter and kept free from disease, their hides have a better texture and are finer-grained. The coarser grades of leather are made from older cattle and those that have little or no shelter in winter.

Oil. — Oil is the name for fat in liquid form. The edible animal fats are butter, lard, and margarine. Mutton tallow is used in the manufacture of candles. Tallow, bone fat, horse fat, and the fat squeezed from the skins of animals are used in the dressing of leather. Animal oils are used in the manufacture of soap, and a large amount of grease is of animal origin. In 1923 the animal and fish oils, fats, and greases produced and used in the United States exceeded one billion pounds and were valued at \$118,432,275.

Buttons. — In addition to the immense number of buttons manufactured from clam and mussel shells, there is a very considerable industry manufacturing other sorts of buttons. In expensive tailoring real horn buttons are used, sliced from the horns of cattle. (However, many of the buttons used on clothing are made from "vegetable ivory," which is a nut and not an animal product.) Great numbers of so-called bone buttons are made from the casein in skim milk. The casein is coagulated, colored, and combined with certain chemicals which give it solidity. These buttons are made by compression. Not only buttons are made by this process, but also umbrella handles, hairbrush handles, and similar products.

SUMMARY

The amphibians showed us the possible origin of land-dwelling animals while the reptiles illustrated a mixed group that seem to be having hard work to maintain their existence when we compare their ancient numbers with the present representatives. In sharp contrast to these two groups are the birds, which are about as numerous and of as many different kinds as the fishes. Flying enables them to escape land and water enemies.

Mammals stand at the top of the vertebrates. They are covered with hair and suckle their young. There are nearly always two pairs of appendages that undergo a wide range of adaptations. The wild mammals still furnish us with our furs, some food, leather, and oil. The importance of this group of animals is so great that regulations governing the killing of them during the breeding season have been made, as well as special efforts to destroy the predatory ones. Our domestic animals which serve us in so many ways have gradually developed into their present form and usefulness. Man had to learn first how to use the fur and skin of wild animals, then how to improve the quality of the fur and skin by careful feeding and breeding of the domesticated animals.

QUESTIONS

How do you tell a mammal from a bird? from a frog? from a fish? What products of mammals do you use daily? What mammals live near your home? Are they beneficial or harmful? How do you know? Where do they live during the summer? during the winter? What is being done to protect the beneficial mammals in your county?

SPECIAL TOPICS FOR DISCUSSION

Many interesting studies can be made of the life of this group. The different kinds of mammals can be detected by their tracks, the distance between footfalls, claw marks on trees, logs, or ground, tooth marks on wood or bone, their nests, shelters, runways, holes, trails, and dust paths — all tell something about each kind. Where do they live, in the soil, among the rocks, in the water, or in the air? What effect do unusual conditions in nature such as storms, floods, or forest fires have? Which animals are active in winter and which inactive? How is the particular mammal you are studying related to other animals? Who are its enemies and its friends? Does it have the same enemies in youth, middle age, and old age? When does it begin to be active each day? How long is it active and when does its activity cease? Does the animal spend the entire year in one locality or does it migrate? If it migrates, in which direction and how far does it go? Can you find out any of the causes of migration, such as food supply and

changes in climate? For those animals that hibernate the time of entering and emerging from hibernation should be observed. Are they completely inactive during this period? As these animals move about during the active season, what is their method of locomotion? Do they run, jump, climb, dig in the ground, swim, or fly? What foods do they eat? Do these foods differ at different seasons? Do they store up any food? Are they dependent on water? What are the various sounds and calls made? Do they have warning calls and alarm calls?

The following observations were made within a few miles of a large city and indicate that a great deal can be learned about the winter life of our common wild mammals.

"The home of the cottontail is where its food grows and in the winter this consists of more than seventy different kinds of shrubs and trees. Among the forms more extensively eaten are the following: bark and soft wood, sumach, bittersweet, high blackberry, bush honeysuckle. The bark only is eaten of sugar maple and barberry, while the young shoots of nearly fifty different kinds of shrubs and trees supply them with food."

The recent great demand for fur coats has enabled many people to start fur farms. If you wish to take up fur farming, write to the Bureau of Animal Industry, Washington, for information.

REFERENCES

Anthony, *Field Book of North American Mammals*, G. P. Putnam's Sons
Ashbrook, *Fur Farming for Profit*, The Macmillan Company
Davenport, *Principles of Breeding*, Ginn and Company
Linville and Kelly, *General Zoölogy*, Ginn and Company
Plumb, *Types and Breeds of Farm Animals*, Ginn and Company
Stone and Cram, *American Animals*, Stone Publishing Company
Warren, *The Beaver: Its Works and Ways*, Williams and Wilkins

Test II

I. Contrast the grasshopper, the butterfly, and the frog according to the following life processes: (Arrange your answers in a tabular form.)

1. Methods of securing food
2. Type of food used
3. Methods of locomotion
4. Adaptation for breathing
5. Kinds of metamorphosis

Study

II. On a separate piece of paper, list the numbers of the following sentences, and opposite these numbers place the word from the right-hand column which makes the statement correct.

- | | |
|--|-----------------------|
| 1. The tadpole gets oxygen in its early stages by means of _____ gills. | four complete |
| 2. Insects have three body regions: head, _____, and abdomen. | temperature bison |
| 3. The abdomen and _____ of certain insects have spiracles. | nest tachina |
| 4. Birds have a higher body _____ than reptiles. | six |
| 5. The _____ bones of birds serve to increase their buoyancy. | trichinosis permanent |
| 6. Clothes moths are destructive in their _____ stage. | nymphs |
| 7. Diptera have _____ wings. | larval |
| 8. Lepidoptera have _____ wings. | pectoral |
| 9. Adult insects generally have _____ legs. | hollow |
| 10. The young of cicadas are called _____. | ocean |
| 11. Lice are insects without _____. | præcocial |
| 12. The _____ fly is a valuable insect which lays its eggs in other insects. | thorax summer |
| 13. The monarch butterfly has a _____ metamorphosis. | wings |
| 14. A disease known as _____ is contracted by eating raw ham or pork. | thorax external |
| 15. The anterior pair of fins on a fish is known as the _____ fins. | altricial two |
| 16. The gill arches of some fish bear sharp pointed projections known as _____ rakers. | mammals gill |
| 17. A small fish, the stickle back, builds a _____ and lays its eggs. | diaphragm |
| 18. Eels lay their eggs in the waters of the _____. | |
| 19. Frogs lack a _____ so that they are unable to take a breath. | |
| 20. Birds, like pheasants, that are active when hatched are called _____. | |
| 21. Birds, like robins, that are inactive when hatched are called _____. | |
| 22. The chickadee is known as a _____ resident. | |
| 23. The bobolink is known as a _____ resident. | |
| 24. Bats are _____ that suckle their young. | |
| 25. A recent mammal saved from extinction by man's knowledge of conservation is the _____. | |

III. On a separate piece of paper, list the numbers of the following sentences, and opposite them place the word from the right-hand column which makes the statement correct.

1. Malaria and yellow fever are carried by _____.
2. In the life history of the monarch butterfly there is the egg, _____, pupa, and adult.
3. The butterfly takes its food by means of a _____.
4. The outside covering of an insect is called an _____.
5. Insects take air into their bodies by means of _____.
6. Sucking insects are controlled by _____ poisons.
7. Biting insects are controlled by _____ poisons.
8. The study of insects is known as _____.
9. The parts of an insect's compound eye are known as _____.
10. Larvæ of insects _____ several times in their development.
11. The head and thorax of crayfish together are called _____.
12. The _____ of a crayfish are protected by the carapace.
13. The crayfish gets _____ by means of gills.
14. The eyes of crayfish are on the ends of _____.
15. Spiders have four pairs of _____.
16. Crustaceans may restore lost parts by means of _____.
17. The largest known crustacean is a _____.
18. The hind legs of frogs have _____ toes.
19. Hibernating frogs get oxygen through the _____.
20. A group of reptiles known as _____ are now extinct.
21. The largest reptile found in the United States is the _____.
22. Snake bites are no longer fatal to man if the proper _____ is promptly administered.
23. The earliest bird artist of the United States was _____.
24. The heart of mammals is a _____ chambered heart.
25. The whale is a _____ that suckles its young.

molt
exoskeleton
regeneration
stomach
dinosaurs
oxygen
lobster
legs
alligator
webbed
mammal
mosquitoes
spiracles
larva
facets
contact
proboscis
entomology
four
gills
cephalothorax
stalks
skin
serum
Audubon

IV. Some of the following sentences are true and some are false. On a separate piece of paper, list at the left the numbers of sentences that are true. At the right, list the numbers of the sentences that are false.

1. Bees make food for man.
- ~~F~~ 2. All insects are adapted for cross-pollination of flowers.
- ~~F~~ 3. A spider is a true insect.
- ~~T~~ 4. Some ladybird beetles help to protect orange trees.
- ~~T~~ 5. Bees and butterflies belong to the same order of insects.
- ~~T~~ 6. Some ants and some aphids are mutually helpful.
- ~~T~~ 7. Boll weevils destroy the leaves of the cotton plant.
- ~~T~~ 8. Codling moths eat the apple-tree leaves.
9. Both the adult and the larva of the potato beetle eat potato leaves.
- ~~T~~ 10. The monarch butterfly migrates in the fall of the year.

V. Both the state and national governments expend large sums of money for the conservation of natural resources. Describe :

1. Two ways in which the conservation of fish is being promoted.
2. Four ways in which insects are being controlled.
3. Two ways in which bird life is being controlled.
4. Two ways in which mammals are being controlled.

UNIT III: THE BIOLOGY OF PLANT LIFE

CHAPTER XVI

INTRODUCTION TO THE FLOWERING PLANTS

The breath of flowers is far sweeter in the air than in the hand.

— BACON

167. The Living Plant. — The life of the apple tree introduced us to biology. The apple tree represents all flowering plants in its various life processes and functions: in beginning life as a sort of condensed plant in the seed; in getting the materials for its food from water, soil, and air; in having roots, stems, leaves, flowers, and fruits; in having enemies which injure these parts; in having the help of a very few insects; in being made up of carbon, hydrogen, oxygen, and other substances; in living for a certain period during which it grows, matures, reproduces its kind, and gradually declines till it finally decomposes, becoming once more a part of the soil and air; and finally in having relations with many animals, especially with man who has learned not only to use it but also to improve it and to combat its enemies.

Not all plants, however, are large, have green leaves, and produce food for man and animals as does the apple tree. The biology of plants or botany requires that we take a broader view of plants and how they live. In this richly varied world there are large plants, like trees, some of which are the largest living things, and small plants, thousands of which can live in a small drop of liquid; plants that are green and those that lack color; helpful plants that man cultivates and harmful ones that he tries to get rid of; plants that live only in water and those that live only on land; plants that produce flowers and fruit and others that do not; plants that live for hundreds of years and plants

that live for only a few hours; plants that like abundance of sunshine and those that prefer dim light.

168. Our Interests in Plants. — Plants are so common that we do not think enough about them. They are, however, very interesting organisms, and they are so important to our welfare that they are entitled to the great amount of attention they have been receiving. In this phase of biology we shall learn why we are so dependent on plants and how their structure fits them to carry on their vital processes.

There are so many different kinds of plants and they live in such a variety of ways that we cannot study them all, but must select a few to give us a general idea of the biology of plant life. We shall begin with the flowering plants and their parts, — leaves, stems, roots, flowers, fruit, and seeds, — essential to the well-being of the plant and the production of new plants.

The general study of the biology of the flowering plants is followed by "Forests and Forestry," which takes up trees and the problems that arise when they become associated with each other, with smaller plants, and with animals.

After studying flowering plants and trees, some of which do not have flowers, we are ready to take up plants that are simpler than these and common, but not so familiar to us, — ferns, mosses, fungi, and algæ, and last, the very simplest organisms, a group which contains both plants and animals. Many of these are so



FIGURE 198. RAM'S HEAD LADY SLIPPER

This is a rare orchid found in a few places in northeastern United States and southeastern Canada. It is apparently doomed to extinction.

minute that they can be seen only with the aid of a microscope. It is interesting that these minute bits of protoplasm exhibit the same phases of life as the towering tree or the huge elephant.

You may have seen pictures of animals and plants that no longer live anywhere on the earth. If you live near a good museum, you can see the remains of these extinct forms. Such animals and plants are known as fossils, and their number and variety

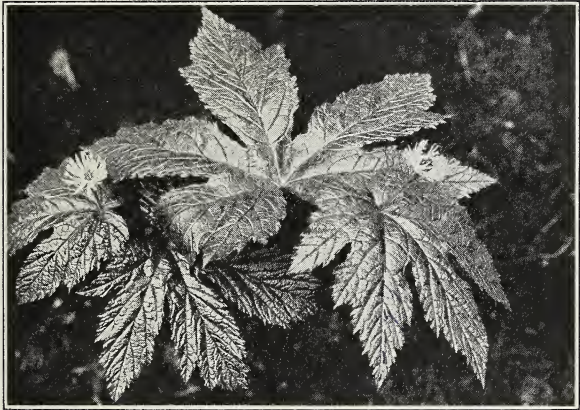


FIGURE 199. LEAVES AND FLOWERS OF GOLDEN SEAL

This plant is dug for its root which has certain medicinal values. It is not common in its wild state as it has been hunted almost to extinction.

are probably as great as those that are alive today. You occasionally read about a new kind of fruit, flower, or animal that has been produced. There is a great deal of study given to this phase of scientific work which is known as heredity, with which we shall conclude "The Biology of Plant Life."

It may be said that plants offer serious problems in human welfare, and that the best efforts of a host of highly trained people are being devoted to trying to solve them. It is the hope of the authors that some of the pupils who study this book may become interested in these problems and join the ranks of investigators.

CHAPTER XVII

LEAVES — THE PLANT'S FACTORY

There's a soul in every leaf!

— BALLOU

169. The Many Functions of Leaves. — The leaf is the part of the plant carrying on the greatest portion of its life processes.

The food for the whole plant is manufactured in the leaves. Digestion takes place in the leaves, and there circulation is started. Respiration and excretion are carried on in the leaves to a greater degree than in any other part of the plant. We shall begin with a study of the structure of a typical leaf, to see how it is adapted to carry on so many processes.

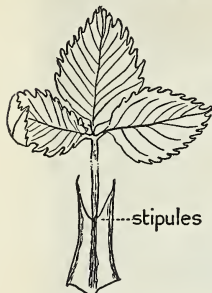


FIGURE 200. LEAF OF STRAWBERRY

What other leaves have stipules?

a leaf is the *blade*. The *petiole* is the part by which it is attached to the twig. This sometimes has small projections called *stipules* at the base.

The leaf of most plants contains veins which determine its main form and serve to keep it firm. There are two main types of arrangement of veins. The first is that in which there are a few veins of about the same size running side by side straight from the base of the leaf to the tip. These are the



FIGURE 201. LEAF OF OAK

The deeply lobed blade is simple.

parallel-veined leaves found in grasses, lilies, and most other monocotyledonous plants (see § 189). In the second type, dicotyledonous plants (§ 189), a few principal veins branch and divide, filling the spaces between them with a fine network of small veins.

171. Leaf Arrangement. — In general, leaves are arranged in two ways: (1) small leaves arranged all along the length of a branch, — the spiral arrangement, — the simplest form of which is found in the elm; (2) opposite, — leaves arranged in pairs on a stem or on a branch, as in the maple. In the first case the shape of the leaves is such that all the space on both sides of the twig is occupied without much overlapping; in the second, every leaf is fully exposed to the light because the lowest leaves have the longest petioles.

A rosette is formed by leaves arranged spirally on a very short stem, with long petioles nearest to the ground, shorter ones alternating with them and filling the spaces.

Light that has passed through one leaf is of little value to a leaf below it. Some plants have finely divided leaves, as the carrot and yarrow, an adaptation which prevents any leaf from shutting off all the light from those below. Angular leaves, round leaves, and leaflets are all adaptations to use up all the space without overlapping. The leaves of ivy growing on a wall are so arranged as to fill all the spaces and not overlap. They form what is called a leaf mosaic.

Most of the grasses show adaptations (1) in having very narrow leaves, fitted to grow close together; (2) in wavy edges if they



FIGURE 202. TWIG OF ELM WITH LEAVES

What is the arrangement? What is the purpose of it?

KEY TO FIGURE 203

TYPICAL LEAVES

1. Net-veined, apple
2. Parallel-veined, corn

COMPOUNDING OF LEAVES

1. Palmate, horse-chestnut
2. Pinnate, butternut
3. Ternate, species unknown

LEAF OUTLINES

1. Apices: *a*, acuminate; *b*, acute; *c*, obtuse; *d*, mucronate; *e*, cuspidate; *f*, truncate; *g*, retuse; *h*, emarginate
2. Margins: *a*, entire; *b*, serrate; *c*, dentate; *d*, crenate; *e*, sinuate; *f*, incised
3. Bases: *a*, cordate; *b*, hastate; *c*, peltate; *d*, auriculate; *e*, sagittate

LEAF SHAPES

- | | | |
|---------------|---------------|-----------------|
| 1. Linear | 4. Elliptical | 7. Orbicular |
| 2. Lanceolate | 5. Ovate | 8. Oblanceolate |
| 3. Oblong | 6. Cuneate | 9. Reniform |
| | 10. Spatulate | |

MODIFICATIONS

1. Barberry (Leaves as thorns)
2. Pitcher Plant
3. Venus's-Flytrap
4. Bladderwort
5. Sundew

Pitcher Plant. — Insects crawl in and drown in the water in the bottom. The plant obtains its nitrogenous food material from the decomposed bodies.

Venus's-Flytrap. — The parts of the leaf fold together quickly when an insect alights or crawls on either side. The long hairs on the edge interlock, preventing its escape. Glands pour out digestive ferments. The digested parts are absorbed, and the halves of the leaf open again.

Sundew. — When an insect touches one of the hairs with glandular tips, that hair and neighboring ones bend over and pour digestive juices on it, holding it till the plant has absorbed the digested food. Then they stand upright again.

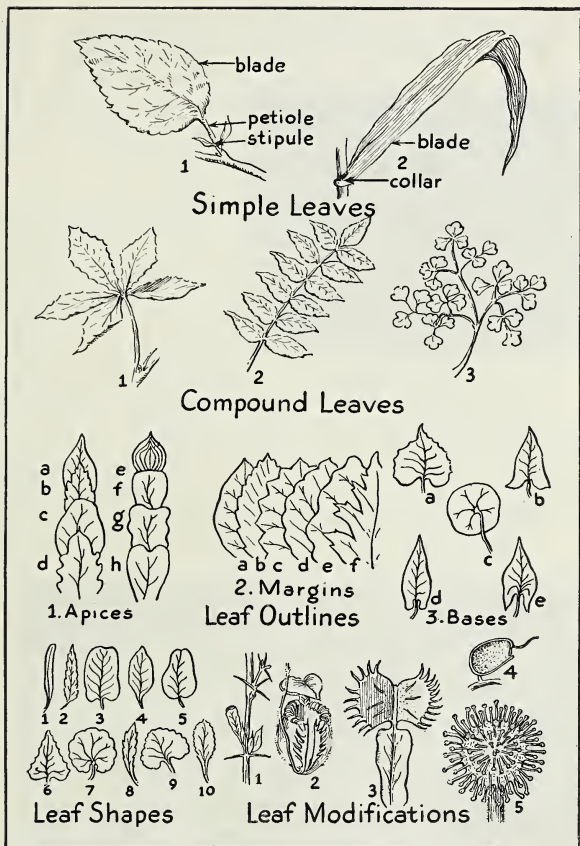


FIGURE 203. LEAVES

are long, an adaptation which prevents their being torn by the wind; (3) in a clasping base, helping to strengthen the stem; and (4) in a collar which prevents water from running down between the clasping base and the stem.



FIGURE 204. ROSETTES OF MULLEIN

Will much grass grow under these rosettes? Give a reason for your answer. What other plants form rosettes? What changes take place in the rosettes?

Whatever the arrangement of leaves on any particular plant, the object of the arrangement is to expose the leaves most advantageously to light and air, and to prevent their shading one another.

172. Simple and Compound Leaves. — A leaf is

said to be *simple* when the blade is all in one piece, and *compound* when it is divided into three or more leaflets. The apple and the

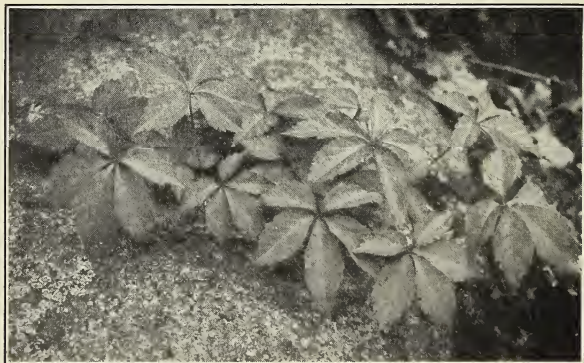


FIGURE 205. PALMATELY COMPOUND LEAVES OF WOODBINE

What other plants have palmately compound leaves?

maple have simple leaves; the clover and the horse-chestnut have compound leaves.

173. Modified Leaves. — Some leaves, like the sundew, pitcher plant, and Venus's-flytrap, are adapted for catching insects for the use of the plant as nitrogenous food. In others, as clematis, the petioles are used to help the plant in climbing. (See Figure 206.) In the case of the pea, leaves have become modified into tendrils which are used in helping the plant to climb. The tendrils of a kind of smilax and some kinds of ivy are also modified leaves. Still others have their leaves modified to thorns for protection, as in the thorny locust and barberry (Figure 207).



FIGURE 206. TWINING PETIOLES OF CLEMATIS

What other plants use their petioles in the same way?

174. The Shedding of Leaves. — The shedding of leaves is brought about by the growth of a layer of cells between the twig and the end of the petiole of the leaf. This seals the ends of the vascular bundles¹ and loosens the leaves. Before a tree sheds its leaves, it withdraws all the food they contain and stores it in some other portion of the tree. What remains is largely the mineral matter that was not needed in the manufacture of food. This is waste, and so of no further use to the tree. The shedding of leaves thus serves two purposes — to reduce *transpiration*² during the period when water is not readily absorbed, and to get rid of waste.

¹ Vascular (fibrovascular) bundles are the conductive systems of a plant. They consist chiefly of two groups of cells, *xylem* and *phloëm*. They are in roots, stem, and leaves. In the leaves we call them veins. In celery and pie-plant they are the "strings."

² The act of sending off water vapor.

Autumn colors appear to be due to a combination of causes, among them the removal of *chlorophyll* (green coloring matter), which has covered up other colors, and chemical changes which take place in the leaf after its work has been done.



FIGURE 207. LEAVES OF BARBERRY TAKEN FROM THE SAME BUSH

What is a thorn? Of what use is it?

“follow the sun.” Others, like the compass plant, turn their edges to direct sunlight which is too strong for them. The clover and oxalis, which fold their leaflets at night, illustrate the so-called “sleep movements” of plants.

175. Leaf Position and Movement. — Usually the position of leaves with reference to the stem is due to the fact that the light is brighter on one side of the plant than on the other. Some leaves on this account

HOME WORK ON PLANT MOVEMENTS

Place young seedlings in a window for a day. Which way do they turn? Turn the plants around and note how long it takes them to change.

Observe leaves of clover and young daisy blossoms. Do they change their positions with the sun? Do other plants do this? Does the age of the plant make any difference in its ability to change position?

Bend a grass stem and fasten it flat. After a day or two observe its position. What changes have taken place?

176. Leaf Structure. — A typical leaf is covered with a layer of thin cells called the *epidermis*. In hot, dry regions the epidermis has a heavy coating of *cutin*, a substance which prevents evaporation. The epidermis on the under side of the leaf is thinner and has less cutin than that on the upper side of the leaf. It is pierced by many openings called *stomata* or air pores which allow the entrance of air and the exit of water vapor and gases.

Between these two layers of epidermis is the *mesophyll* (mēs'ō-fil) of the leaf, divided into two regions: (1) the *upper* or *palisade*, composed of slender, elongated cells placed side by side in an upright position, and (2) the *spongy layer* consisting of rounded cells, loosely arranged with many air spaces between them. The palisade layer contains the most chlorophyll.

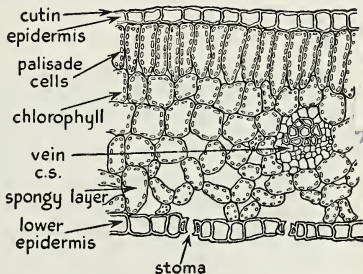


FIGURE 208. STRUCTURE OF A LEAF
How is each part adapted to do its work?

LABORATORY STUDY OF
LEAVES

Study a section of a leaf and test every statement in this chapter about the structure of leaves.

Stand a stalk of celery in water tinted with red ink. Cut across it after two hours and observe the position of the vascular bundles. Trace them into the leaf.

Study a bit of epidermis with a microscope. Draw. Label stomata, epidermal cells, guard cells (2 around each stoma). Study a cross section. Label *cuticle* (outermost layer), *epidermis* (upper and under surfaces), *palisade layer* (under top epidermis), *spongy layer* (body of leaf), *vein*. Which cells contain chlorophyll? Where are the air spaces?

HOME WORK ON LEAVES

Pull up or cut off a large burdock plant. Measure the area covered by the lower leaves. What else grew in this area? What is its condition? Why? What plants form rosettes of leaves in the fall?

Break off leaves of burdock, plantain, dock, and pieplant. Note the strings (fibrovascular bundles).

Make a collection of leaves to illustrate the various kinds of shape, apex, margin, and base.

What effect does wind have in helping or hindering leaves in getting light? What happens when you make a "bag" from a leaf of live-for-ever?

177. How the Stomata Perform Their Function. — The cutin of the epidermis prevents too rapid evaporation of water. In a leaf that extends horizontally from a plant, most of the stomata

are on the under side, an adaptation which prevents their being closed by water or dust. In leaves that float upon the water,

the stomata are on the upper surface. Plants with erect leaves have stomata distributed on both sides. In desert plants they are sunk below the level of the epidermis, or they are covered by hairs or wax, both of which tend to keep them from being filled with water and to prevent undue transpiration. The structure shows other adaptations. The opening is surrounded by two cells, called *guard cells*, which have the property of absorbing water from the atmosphere. When these cells are full of moisture, they are plump or *turgid*; when they have only a little water,

they are flabby or *flaccid*. The turgid guard cells leave the stomata wide open and allow free passage of air into the cell, and of water and gases out of it. Flaccid guard cells, on the other hand, make the opening small, decrease the amount of air that enters, and prevent undue evaporation from the inside of the leaf. Although the stomata are very small, they are so numerous that their combined action accomplishes a great deal. A square millimeter of the under surface of a lilac leaf contains 330 stomata, that of white birch, 237.

178. Functions of Leaves. — The life processes carried on by the leaf are (1) *photosynthesis*, peculiar to plants having chlorophyll, green coloring matter; (2) *respiration*, common to all living protoplasm; (3) *digestion*; (4) *circulation*; (5) *assimila-*



FIGURE 209. EPIDERMIS OF A LEAF

The epidermal cells lack chlorophyll. What is the function of the epidermis?

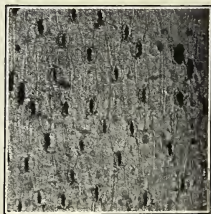


FIGURE 210. PHOTOMICROGRAPH OF EPIDERMIS OF ONION

Compare the shape of the cells and the position of the stomata with those of Figure 209. Are these characteristic of all monocotyledonous plants?

tion, and (6) *excretion*. In a few plants, leaves reproduce vegetatively, i. e., without egg and sperm. All but photosynthesis are much the same as the processes of the same names in animals. *Transpiration*, which, like photosynthesis, is peculiar to green plants, is not a life process, yet is made necessary by these processes (see § 180).

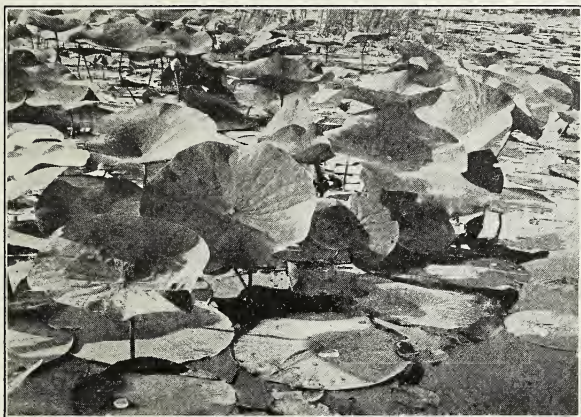


FIGURE 211. FLOATING LEAVES OF AMERICAN LOTUS

These have stomata on the upper surface. Would you expect to find stomata on the submerged petioles?

179. Photosynthesis, the Manufacture of Carbohydrates. — The word *photosynthesis*, as we saw in § 30, means putting together by means of light. It is the process of manufacturing carbohydrates from raw materials, a process vital to the entire living world and performed only by green plants.

Comparison. — The process of photosynthesis may be compared to manufacturing processes. In this comparison the *products* are the carbohydrates and other forms of food which are made from them, and the *by-product* is oxygen. This manufacturing process disposes of its products (1) by storing certain of them on the premises, the leaf; (2) by using them on the premises to make

more protoplasm or to furnish energy; (3) by sending them away to other parts for storage.

In the process of photosynthesis, the first visible, stable product is one of the carbohydrates. Proteins and oils, also found in plants, are made by processes which follow photosynthesis and depend on a supply of carbohydrates. There are many things concerning the manufacture of foods by green plants that we do not yet know, though we are sure of a few facts. In the case of carbohydrates, we know that the raw materials are carbon dioxide, obtained chiefly from the air in very small quantities, and water, obtained from the soil by the roots. We know, too, that chlorophyll is one of the essentials, and that bright light is another, also that oxygen is given off as a by-product. In the case of proteins and oils, made in the leaf as are the carbohydrates, the presence of chlorophyll and light are not essential. Proteins contain a number of substances, especially nitrogen, that entered the plant with the water in the form of solutions. Since green plants are the one and only source of food, it is evident that we are fundamentally dependent on them. Some foods, to be sure, are not made directly by plants, — meat, eggs, milk, — but are derived from animals that live upon plants.

The blanching of celery illustrates the fact that chlorophyll cannot develop in darkness. The white leaves in the heart of a head of cabbage, lettuce, or in opening buds in the spring are also accounted for by the fact that they are shut off from light by the leaves which surround them.

HOME WORK ON PHOTOSYNTHESIS

Make a list of the plants that are used for food. Look up in an encyclopedia the amounts of each produced in a given year. Make a list of the industries which are dependent on agriculture. Obtain information concerning the number of men employed in each.

What uses are made of starch and sugar aside from food?

What are the sources of protein used as human food? Which of these depend directly upon photosynthesis? Which indirectly upon it?

Look for plants that have grown in the dark, such as the sprouts on potatoes, plants under boards, etc.² Put them in a strong light. See what happens. Account for everything you see.

LABORATORY WORK

Necessity for Light. — Review the laboratory work in § 30, page 40.

Liberation of Gas. — To test the nature of the gas given off by green plants in growing and making food, collect a quantity of algæ, *Elodea*, or *Sagittaria* and place it in a deep glass jar in the sunlight. When bubbles begin to show, place an inverted funnel over the plants. Fill a test tube with water and invert it over the upright stem of the funnel. When an inch or more of the gas has collected in the test tube, remove it carefully, and thrust a glowing splinter into it. Increased brightness of the glow or bursting into flame shows that oxygen is present.

180. Transpiration. — This is the process of excretion of water from plants, water in the form of vapor escaping through the stomata. It is closely connected with the vital processes though not one of them. Its only similarity to perspiration in animals, to which it has sometimes been likened, is that water is given off through openings in the outer covering of the plant. Transpiration is unavoidable because the roots of a plant usually take up more water than is needed for the vital processes, and because this excess accumulates in spaces which communicate with the outside through the stomata. When transpiration is too rapid, the plant is deprived of needed water.

As we saw in § 177, the position of the stomata on a leaf and their structure help regulate transpiration. A leaf may further check transpiration by changing its position or by rolling its edges together. Corn leaves during a very dry period illustrate the latter. Another device is seen in cactus plants, which have a greatly reduced surface. As the stem in these plants is green and contains stomata, it is thus enabled to do the work of leaves.

When the moisture in the air exceeds a certain quantity, evaporation does not take place readily. At such times too much water accumulates in the plant. To prevent damage from this condition, plants have modified stomata, called *water pores*, at the ends of the veins. These contain cells which burst under pressure, allowing the water to exude. This process is known as *guttation*, and the drops so formed are known as *guttation drops*.

Guttation drops are sometimes absorbed again by the plant and sometimes they evaporate, depending on the needs of the plant and the amount of moisture in the air. The amount of water that leaves a plant in a day by transpiration alone is very great. For example, a moderate-sized sunflower plant will give off a quart a day under ordinary conditions.

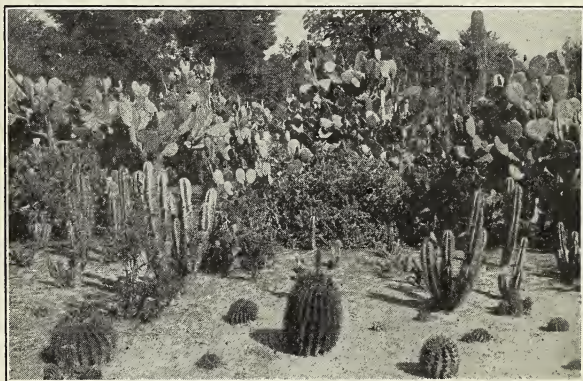


FIGURE 212. A CACTUS DISPLAY

The stem of the cactus performs photosynthesis. The plant is adapted to reduce transpiration. What adaptations have the forms of cactus that are used as house plants?

LABORATORY WORK ON TRANSPIRATION

Liberation of Water Vapor. — Turn the under side of a geranium leaf or other large leaf so it lies against a cool window pane, holding it there in some way if necessary. After half an hour remove it and note the drops of moisture which resulted from transpiration.

Take three leaves from the same plant. Coat one on both sides with vaseline, one on the upper side only, and one on the lower side only. Lay them aside till your next laboratory period. Then describe all three. Which is least wilted? Why? Use an uncoated leaf as a means to insure accuracy in your conclusions.

Cover a small fuchsia or balsam overnight with a bell jar. Where are the guttation drops found? Why do they form there?

181. Excretion. — Plants, like animals, excrete or remove from their system material or substances which are harmful or no longer of use to the plant. These are not always removed promptly, but are sometimes stored where they can do no harm. An example of this is the crystals of calcium oxalate which give to sorrel, or sour grass, its sour taste.

182. Digestion. — Plants, like animals, cannot make use of some kinds of food until it has been digested (simplified and dissolved). This process of digestion takes place chiefly in the leaf, and the digested food is carried to all parts of the plant which need it through the vascular bundles. There are many facts about digestion in plants which are not so well understood as this same process in animals. It is known, however, that the enzyme, *diastase*, which digests starch, is secreted by the protoplasm of the cells and that it is very similar to *ptyalin*, the ferment in the saliva of animals which digests starch.

183. Circulation. — Circulation in plants differs from circulation in animals in not having any central organ as a heart for keeping the fluids in motion. *Sap* (the fluid in plants) is moved by the combined influence of osmosis (root pressure), transpiration, and possibly other factors. The xylem of a fibrovascular bundle (see page 223, note) carries water taken up by the roots from the soil to the leaves, where it is combined with carbon dioxide from the air and built up into foods. The digested foods are carried from the leaf to the parts of the plant which need them in the phloëm part of the vascular bundle, so that, generally speaking, we have an ascending stream of water in one

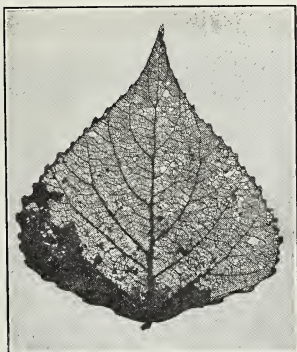


FIGURE 213. SKELETON OF A POPLAR LEAF

Part of the epidermis still remains. Poplar leaves skeletonize easily. What other leaves have you seen that were skeletonized wholly or in part? What two functions do the veins of a leaf perform?

part of the bundle and a descending stream of digested food in the other part. The term *sap* is used to include both.

184. Respiration. — Respiration in plants is exactly the same as in animals. Every living cell must have oxygen to combine with some of its protoplasm, releasing energy for the work of the plant and forming carbon dioxide and other wastes in the process.



FIGURE 214. INDIAN PIPES

This plant is white and waxy. Can it make its own food?

Air, entering through the stomata, furnishes oxygen for respiration as well as carbon dioxide for photosynthesis. Since oxygen is one of the wastes of photosynthesis, it is possible that some of it is used for respiration as soon as it is set free. Because of this, plant respiration is most easily studied in plants like toadstools, which cannot perform photosynthesis, and in sprouting seedlings, which have not developed chlorophyll.

the digested food as they need. By assimilation the old cells are repaired and new ones grow. As in animals, it is a building-up process which results in the growth of the plant till it reaches the stage of maturity and maintains it at that size.

186. Economic Uses of Leaves. — The leaves of grasses as well as their stalks are used as food for cattle. Man uses for food the leaves of many plants, and as a beverage, the leaves of the tea plant. The leaves of wintergreen, spearmint, peppermint, and sage are used for flavoring, and the leaves of mullein, boneset, catnip, peppermint, wintergreen, wormwood, and many other plants, for medicine. In the tropical countries some broad leaves are used for thatching, thus affording shelter.

185. Assimilation. — This is the actual taking up by the plant cells of such parts of

187. Plants without Leaves. — In plants like the cactus, the work usually done by leaves is done by the stem. In the asparagus the stem, which branches again and again, also serves as leaves, the true leaves being almost invisible scales.

Other plants which have scales instead of leaves are dodder and Indian pipe, both of which use food already prepared.

SUMMARY

As you turn your attention from the plant as a whole to study the work of its separate organs, you find that the leaf is "nature's laboratory" for the manufacture of food. Of all the organs of the plant, the leaf is the one in which the vital processes are carried on to the greatest degree, for in the leaf food is manufactured, digested, and assimilated. Its cells also carry on respiration and excretion more than any other cells of the plant. This is the reason why shape, size, arrangement, and structure are all adapted to obtain for the leaves the greatest possible amount of light and air. The root and the stem exist in order to help the leaf in its work. Since photosynthesis is the only known way of making food, the leaves of green plants provide the food supply for the whole world. Leaves sometimes serve to help to support a plant, and in some food is stored. Roots, stems, and leaves all work together to help the plant produce flowers, fruit, and seeds, the climax of the plant's activity.

QUESTIONS

Name the processes carried on by leaves. Which is of the greatest use to man? Why? What is the object of leaf arrangement? Describe the structure of a leaf. What two purposes are served by veins? Mention at least four plants that have peculiar leaves. Describe each leaf and tell how it helps the plant.

SPECIAL TOPICS FOR DISCUSSION

1. Collect information to prove or disprove each of the following statements:

Man makes more use of the

- (1) stems than of other parts of plants.
- (2) leaves than of other parts of plants.
- (3) roots than of other parts of plants.
- (4) flowers than of other parts of plants.
- (5) fruits than of other parts of plants.
- (6) seeds than of other parts of plants.

2. Substitute *Wild animals make* for *Man makes* and make a new survey of the facts in Topic 1.
3. Select twenty or more definite statements about photosynthesis from an advanced botany, and make a set of true-false statements for a quiz.
4. Compare and contrast plant physiology with animal physiology.
5. Make a list of the cultivated plants which man propagates by other methods than planting seeds.
6. What plants do you know of that can be propagated by leaves?

REFERENCES

- Bergen and Caldwell, *Introduction to Botany*, pages 34-84, Ginn and Company
- Bergen and Caldwell, *Practical Botany*, pages 13-20, 39-103, Ginn and Company
- Bergen and Davis, *Principles of Botany*, Chapters X, XI, XII, Ginn and Company
- Conn, *Biology*, pages 114, 129, 135, 217-226, Silver, Burdett and Company
- Cook, *College Botany*, pages 70-81, J. B. Lippincott Company
- Coulter, Barnes, and Cowles, *Textbook of Botany*, Volume I, pages 250, 319-343, American Book Company
- Curtiss, *Nature and Development of Plants* (seventh edition, revised), Chapter I, Henry Holt and Company
- Eyster, *College Botany*, Chapter IX, Richard R. Smith Company
- Gager, *Fundamentals of Botany*, pages 26-46, Blakiston's Son and Company
- Gibson, *Sharp Eyes*, pages 121-127 (out of print)
- Holman and Robbins, *A Textbook of General Botany* (second edition), pages 181-233, John Wiley and Sons
- Mottier, *College Textbook of Botany*, Chapter II, Blakiston's Son and Company
- Rigg, *College Botany*, Chapter II, Lea and Febiger
- Robbins and Rickett, *Botany*, pages 64-74, D. Van Nostrand and Company
- Sinnott, *Botany, Principles and Problems*, pages 63-87, McGraw Hill Publishing Company
- Smith (and others), *A Textbook of General Botany*, pages 42-52, The Macmillan Company
- Snyder, *General Science*, page 358, Allyn and Bacon
- Torrey, Ray E., *General Botany for Colleges*, Chapter V, The Century Company
- Transeau, *General Botany*, pages 22-89, World Book Company

CHAPTER XVIII

THE STEM — THE PLANT'S SUPPORT AND ORGAN OF CIRCULATION

*The willows wrap
Their stems in furry white.*

— HELEN HUNT JACKSON

188. The Stem in a Double Rôle. — We have seen that the most important part of the plant's work is done by the leaves, and we have learned that the leaves are so arranged as to get the largest possible amount of air and light. We have learned also that the water and dissolved substances which the plant needs for making food are gathered by roots in the soil. The stem is the path by which the solution reaches the leaves and, in many cases, the path by which the food returns to be stored in roots. This is our reason for calling it the plant's organ of circulation. It is more than that, however, for the stem supports the leaves, and must contain conductive vessels to enable it to serve its first function.

189. Two Kinds of Stems. — There are only two kinds of stems as far as structure is concerned. In one kind (monocotyledonous, having one seed leaf), the fibrovascular bundles are scattered throughout the pith. Such stems are always found in plants that have one cotyledon (seed leaf), as corn, grass, and palm. In the other kind of stem (dicotyledonous, having two seed leaves), the bundles are arranged around the outside of the pith and, in the early stages, have pith between them also. Such stems are always found in plants that have two cotyledons, as the bean and all woody trees.

190. Fibrovascular Bundles of Monocotyledonous Plants. — A vascular bundle (see page 236) in a monocotyledonous plant is made up of two kinds of cells or groups of cells called *xylem*

KEY TO FIGURE 215

TYPES OF BRANCHING

1. An excurrent stem does not divide from base to tip. Its branches arise in irregular whorls from the sides.
2. Most trees are intermediate between (1) the excurrent type and (3) the deliquescent type.
3. A deliquescent stem divides repeatedly, resulting in many branches of about the same size.

POSITION OF STEMS

Strong stems stand upright. Weaker ones that lie on the ground, put out bare branches called stolons or runners for propagation. This is a creeping stem. Another that lies on the ground without taking root is illustrated by hop clover.

To hold themselves up in the air, weak stems use tendrils, like bryony, or aerial roots, like ivy, or twine their stems about a support like the bindweed.

SPECIALIZED STEMS

1. In florist's smilax, the broad expansions of the main stem are not leaves, but branches of the stem.
2. The rhizome is a thickened, fleshy stem that grows underground, putting up aerial branches and storing food for next season's growth.
3. The tuber is a shortened underground stem also used for storage. In a potato, the "eyes" are buds of aerial branches.
4. Bulbs have shortened stems to which the thickened bases of leaves are attached. Food is stored in the leaves.
5. Corms are solid underground stems shaped like a bulb.
6. Reduced stems are seen in plants that lie close to the ground with their leaves in a close rosette.
7. The thorns of honey locust are short, sharp branches.

LABORATORY SUGGESTIONS

How does branching influence the shape of a plant?

What is the purpose of branching?

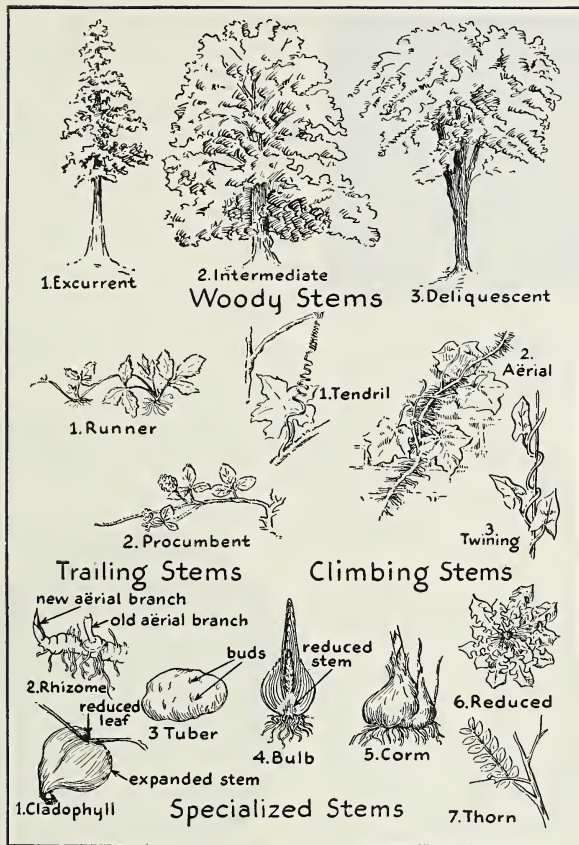


FIGURE 215. STEMS

Woody Stems: 1, Sequoia; 2, Chestnut; 3, Elm.

Trailing Stems: 1, Strawberry; 2, Hop clover.

Climbing Stems: 1, Bryony; 2, Ivy; 3, Bindweed.

Specialized Stems: 1, Smilax; 2, Solomon's Seal; 3, Potato; 4, Hyacinth; 5, Crocus; 6, Dandelion; 7, Honey locust.

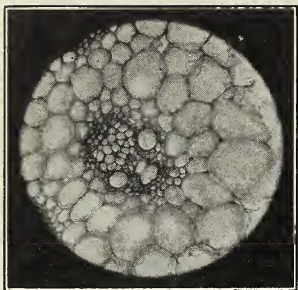


FIGURE 216. CROSS SECTION OF A FIBROVASCULAR BUNDLE (CORN)

Which is on the right side, xylem or phloem? How can you tell?

xylem cells and they communicate with one another through the ends and not through the sides. The ends of these cells have perforated plates through which the liquid in the cells passes. These are called *sieve plates*.

191. Fibrovascular Bundles of Dicotyledonous Plants.—A fibrovascular bundle in a woody stem has *three* groups of cells: the *xylem*, on the inside, some of its cells thick-walled, with thin spots; the *phloem*, on the outside, thin-walled cells with sieve plates at the ends of the larger cells; and the *cambium*, small, brick-shaped, thin-walled cells. The cambium lies in a narrow strip between the xylem and the phloem.

(zī'lēm) and *phloēm* (flō'ēm). The xylem cells are thick-walled, but have thin spots in each cell where it touches another cell of the same kind. Each cell is long and pointed. Some of them overlap so that they make practically continuous tubes from the root, up through the stem, and into the leaves. The thick walls help to give firmness to the plant.

The phloem cells are the other part of the vascular bundle in a monocotyledonous stem. They have thinner walls than the

hard rind pith fibro-vascular bundles

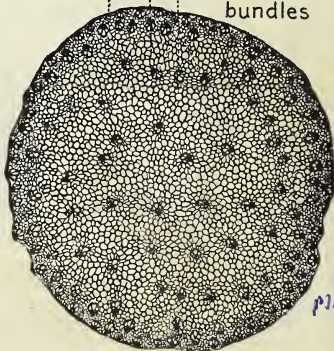


FIGURE 217. CROSS SECTION OF A MONOCOTYLEDONOUS STEM (CORN)

Note the fibrovascular bundles scattered through the pith. Which cells are the largest?

In woody stems, the cambium is the part which makes it possible for the stem to increase in diameter. This increase is brought about as follows: the brick-shaped cells on the inside edge of the cambium layer gradually change to the thick-walled xylem cells, and those on the outside of the layer turn to thin-walled phloëm cells. As more and more bundles grow in the ring, the cambium layers touch and become a continuous ring. Thus it happens that a woody stem can add a layer of wood on the inside of the cambium, and a layer of phloëm on the outside every year. It is easier to trace the woody rings, however, for they are protected and do not change, while the bark formed from the phloëm cracks and falls off in bits, making it difficult to trace the annual rings.

LABORATORY STUDY

Place a living pea seedling in water containing eosin, or red ink. If possible, use one that has been germinated in sawdust in a paper cup, make a hole in the bottom of the cup, and set it in a tumbler of water containing the eosin or red ink. After two or three hours note the presence of the stain in the stems and leaves.

192. Structure of Monocotyledonous Stems. — In the cornstalk, a monocotyledonous stem, the vascular bundles are scattered throughout the central pith and have no definite position with reference to the center, except that the larger and older ones are arranged toward the center and the smaller and younger ones near the edge. The outside of the stem is covered with a hard rind which often contains silica, a substance like glass which makes it hard and strong. The function of this rind is mainly to support the plant. In grasses, the stem is hollow, and the bundles are of course around the edges, some of them passing off at each node into the leaf that arises from the node.

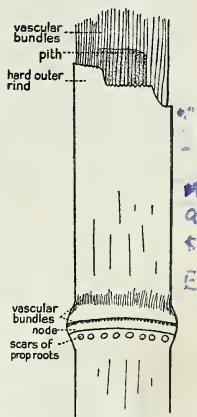


FIGURE 218. PORTION OF CORN STEM

What was the work of the fibrovascular bundles that show at the node?

193. Structure of a Woody Stem. — External. — As an example of a woody stem, we shall study a horse-chestnut twig. On the outside is a brownish bark, some scars showing the position of last year's leaves, and some rings

extending around the twig, indicating where the scales were attached that covered the bud containing these leaves. Above a leaf scar is a bud covered with sticky scales, and at the end, a large terminal bud.

The buds that grow above the leaves are called *axillary* buds. If more than one of these are found in an axil, the additional ones are called *accessory* buds. The strength of the terminal bud determines the stem's method of branching.

Very soon after the leaves have reached their full size in the spring, the buds for next season's stem and leaves are formed. Buds are protected in winter by coverings of scales which prevent them from becoming dry. A bud may contain stem and leaves only, or flowers only, or both. Small markings on the smooth bark are *lenticels*, spots where the outer layer of the branch is broken, allowing air to enter the inner portions.

Pith, which occupies the center of a stem, is made up of large cells with thin walls. In the early stages of the plant's life, it serves as a place for the storage of food. Later it dies, and in an old stem often turns brown. Pith is smaller in an old stem than in a young one, as the woody layers crowd and compress

it. Near the outside of the stem are the *fibrovascular bundles*, which contain the conductive vessels (see § 191) of the plant. In a young stem, these lie in an incomplete ring with broad strips of pith between them.

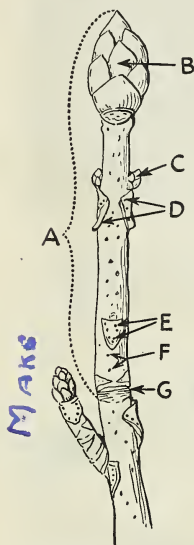


FIGURE 219. TWIG OF HORSE-CHESTNUT

A, growth made last season; B, terminal bud; C, axillary bud; D, leaf scar; E, fibrovascular bundles; F, lenticels; G, rings made by scales of last year's terminal bud.

The rays of pith between the fibrovascular bundles of a young woody stem are gradually compressed, forming narrow radiating lines extending towards the bark. In older stems similar lines, originating in the cambium, extend towards the pith. Both of these are known as medullary rays. These are cells of a special kind, the functions of which are to store food and to form a connection between the outer and the inner parts of the stem.

The bark of an older stem and the epidermis of a young stem protect them from drying out, from the attacks of insects, and from the entrance of bacteria, spores, and fungi. Because of their porous structure they also admit air to the interior of the stem. All these parts, pith, woody portion, phloëm, pith rays, and epidermis or bark, combine to make up the stem, and at the same time each has a definite service to perform in the life of the whole plant.

194. Functions and Adaptations of Stems. — The stem, as we have learned, is used for the support and attachment of leaves, and to provide a path for the vessels that carry water from the roots where it is gathered to the leaves where most of it is used. Another use of stems is for the storage of food, as in the potato. A few plants make use of stems for propagation, as in the case of the strawberry and the black raspberry. (See § 197.)

The stem is adapted to its work (1) in being compact and sturdy, able to bear weight; (2) in branching, which usually affords a larger number of points for the attachment of leaves and a larger space in which to display them; (3) in being covered with a strong epidermis or, in woody stems, with bark

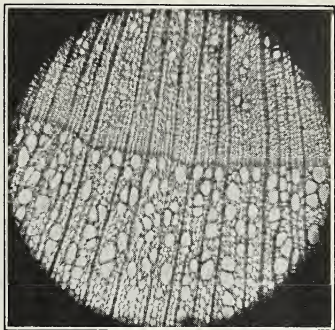


FIGURE 220. CROSS SECTION OF WOODY STEM

Where is the annual ring?

which protects it from outside injury and keeps it from drying up; (4) in plants which grow in the water, in having large air spaces to carry air to the roots which lie in the mud at the bottom of the water; (5) in being provided in some cases with thorns or briars, as in the blackberry and rose, to protect it from being injured by animals.

The hard outer rind makes a monocotyledonous stem rigid, and the pith makes it light. Monocotyledonous stems are usually

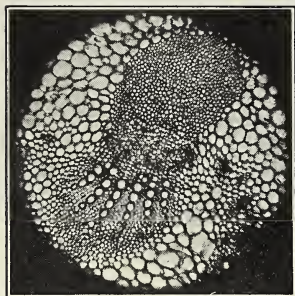


FIGURE 221. CROSS SECTION OF A DICOTYLEDONOUS STEM (SUNFLOWER)

Note the xylem grouped in lines near the center.

tall and slender and do not sustain great weight. A dicotyledonous stem is usually stouter, and its woody structure enables it to bear a heavy load of leaves and fruit.

195. Growth of Stems. — Most woody plants grow rapidly in the spring and early summer, after which they stop increasing in size but continue to add material within the limits attained. This makes wood and enables the stems to resist being killed in the winter. Such plants are said

to have a *definite annual growth*, a process illustrated by most woody trees. The advantages of definite annual growth are twofold: (1) it enables a tree to grow very rapidly in the spring when conditions are most favorable for growth, and (2) it does not result in the loss of any wood once formed.

Some plants continue to grow until the end of the season. The ends of the twigs in such plants, with the buds on them, are usually killed by the frost. The plant begins to grow next season from axillary buds below the point where it was killed. Such plants are said to have *indefinite annual growth*. Examples are red raspberry and sumac.

The plant which makes an indefinite annual growth can take advantage of favorable growing conditions whenever they occur,

although it may lose some of its youngest wood if frost comes before the wood is hard enough to resist it.

In the annual growth of woody stems, a new part is added to each branch and a new layer of wood over the wood of previous years. This makes it possible to tell approximately how many years old a tree is, the growth of each year forming a ring more or less distinct according to conditions. When the conditions for growth are at their best, the cells formed are large. As conditions become less favorable, the cells become smaller and have thicker walls, marking distinctly the end of one season's growth from the beginning of the next. The size of the cells varies greatly in different trees, producing the different "grains" of lumber.

196. The Duration of Stems. — The length of life of a stem depends upon the plant's method of producing seeds. An annual or herbaceous stem, like the morning-glory or corn, dies at the end of the first season, the plant having produced its seeds. Other stems, like trees, last year after year. Some of the redwood trees in California are known to be more than three thousand years old, and the cedar of Lebanon, growing in Asia Minor, is known to live equally long.

197. Stems as a Means of Propagation. — Stems are used in various ways in propagating plants. "Slipping" plants is a common practice, the success of which is due to the fact that new roots grow readily from the cut end of a branch of geranium,



FIGURE 222. EXCURRENT TRUNK (STEM)
OF EVERGREENS

The trees in the foreground are redwoods, probably hundreds of years old. What other kinds of evergreens grow in the same forests with redwoods?

balsam, ivy, and some other plants. Two advantages make slipping popular: (1) the certainty of securing a new plant like the parent plant, (2) the short time required to produce blooms compared with that for the same kind of plant raised from the seed. Willow twigs root so readily that it is often possible to start a hedge by sticking pieces of branches into the ground when it is very wet.

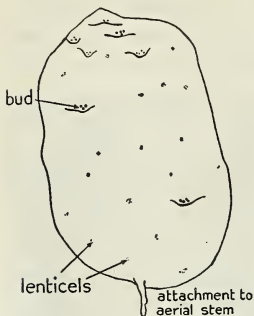


FIGURE 223. POTATO, A TUBER

A common form of underground stem used for storing food, chiefly starch. Is potato an annual, a biennial, or a perennial?

198. Specialized Stems.—In regions where the climate is very hot and dry most of the year, the leaf surface is greatly reduced to prevent undue evaporation. In this case the stem becomes green and performs the work of photosynthesis (see page 38), ordinarily done by leaves. The cactus illustrates this. Certain other plants such as asparagus have no leaves, but

the stem branches in such a way as to resemble leaves.

199. Underground Stems.—An underground stem can always be distinguished from a root by the buds of new shoots or the scars of old leaves, although in some stems the leaves are reduced to mere scales, as in the potato. Underground stems usually send up aerial shoots. They often have an advantage over an aerial stem in being better protected. Some plants make use of the underground stem in propagating themselves.

Canada thistles, quack

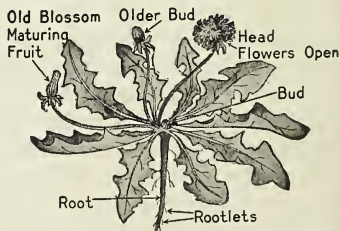


FIGURE 224. DANDELION

Dandelion has no visible stem. How is this an advantage? Do dandelions under all conditions have their leaves nearly horizontal?

grass, and devil's-paintbrush are among the most difficult weeds to eradicate because of their branching, underground stems, each piece of which when broken off can form a new plant. In digging dandelions from lawns, care must be taken to cut deeply enough to remove the whole crown of the plant, otherwise the injured part branches and forms a weed more troublesome than the original one.

LABORATORY STUDY OF UNDERGROUND STEMS

Draw a potato. Label the "eyes," *buds*. On which end are they more numerous? Label *scale*, just below *bud*. Note end where the potato was attached to the main plant.

Cut off the stem end and stand the cut surface of the potato in water colored with red ink. After two hours examine again and note what part is stained. Cut off slices till traces of color disappear. Draw to show where it is colored. Cut a thin slice and put a few drops of weak iodine on it. What happens? What does it show?

Cut an onion bulb vertically. Note the condensed stem on which the leaves are arranged.

200. Value of Stems to Man. — Man uses some stems for food, the white potato being one of the most familiar as well as important examples of such use. Starch is also made from potatoes. The stem of asparagus is a valuable food.

A second use of stems is for shelter. Huts are sometimes made of bamboo. Trees furnish lumber in all its varieties. Some parts of houses can be made from stone, brick, or other materials, but for the inside finishing we are still largely dependent upon wood.

A third use is for furniture. No other material has been found so satisfactory as wood for tables and chairs.

A fourth use is for clothing. The flax plant which furnishes the material from which linen is made is one of the most valuable. Its usefulness depends upon strong fibers called *bast fibers* which are found in the outer part of the slender stem and serve to give

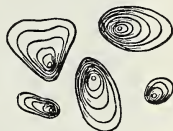


FIGURE 225. GRAINS OF POTATO STARCH, MUCH MAGNIFIED

Most kinds of starch have characteristic markings. In what other objects studied have you found similar markings?

it stiffness. When separated from the other parts of the stem, they can be twisted, spun, and woven.

Fifth, the stems as well as the leaves of peppermint, boneset, wormwood, catnip, foxglove, and other plants are used as medicine.



Ewing Galloway

FIGURE 226. WORKMEN'S HOMES ON A BIG CACAO PLANTATION

How many uses of "stems" can you see in this picture?

A sixth use is for cordage. This includes all kinds of ropes and many kinds of strings. Some cordage is obtained from fibers of hemp, and some from other plants.

Seventh, in many places wood used as fuel is the only source of heat for cooking and keeping warm in winter.

Among the many other uses of stems in our daily life may be mentioned poles for telegraph, telephone, and electric light wires, masts of ships, piles of piers, timbers for props of mines, lumber for bridge foundations, railroad ties, parts of implements and tools of daily use, vehicles, and parts of machines. Add to these the boxes, barrels, crates, trunks, pails, baskets, and other common articles which we use frequently, and paper in its many

forms and numerous uses. It is evident from this extensive list, which is far from complete, that man is seriously dependent on the stems of plants and that he could not well do without them in his daily life.

Adaptations of Wood. — When we compare the number of articles that are made of wood with the same articles made of substitutes, we see that there are some good reasons for the use of wood. Among these are its *lightness* compared with iron or steel for use in furniture, trunks, and other articles, its *pliability*, its *toughness*, its *durability*, especially when protected from dampness, the *ease* with which it can be shaped by tools, and its *beauty*, which depends on color and grain, and on the high polish that it can take.

SUMMARY

You have now begun the study of the separate parts of the plant, but you must keep in mind that, however important any one part, the plant as a whole cannot live and thrive unless all its organs work together. Stems have a wide range of form and size, but the function of a stem is always the same, namely, to form the connection between the roots, which gather raw material for the manufacture of food, and the leaves, where the food is actually made. Stems are compact and sturdy because they must bear the weight of the leaves, branches, flowers, and fruit, and because the vessels through which liquids are conducted must be well protected. Most stems grow above ground and upright, but some lie on the surface of the ground and some below the soil. The stem of the woody plants is employed by man in more ways than any other part, furnishing him shelter, fuel, furniture, clothing, paper, parts of many machines, and implements on which he is daily dependent. Some stems are a source of food for man and the stems of grasses furnish food for many animals.

QUESTIONS

What is the stem? What is its use to the plant? What positions do stems take? How long do they live? Name and describe the peculiar stems. What are vascular bundles? How are they arranged in a monocotyledonous stem? in a dicotyledonous stem? What is their work? What is definite annual growth? indefinite annual growth? What are annual rings? How are they formed?

SPECIAL TOPICS FOR DISCUSSION

1. Defend or refute the following statements:

Modern civilization depends chiefly on stems.

When the present primeval forests are cut down, there will never again exist trees of so great a size nor trees so old.

An invention by which waste paper could be made to serve as a substitute for wood would be a help in conserving forests.

2. Write an essay using the facts you find about the manufacture and use of artificial silk or rayon.

REFERENCES

Bergen and Caldwell, *Introduction to Botany*, pages 56-124, Ginn and Company

Bergen and Caldwell, *Practical Botany*, pages 11-13, 39-103, Ginn and Company

Cook, *College Botany*, pages 31-58, J. B. Lippincott Company

Coulter, *Plant Life and Plant Uses*, pages 49, 143-193, D. Appleton and Company

Eyster, *College Botany*, Chapter VIII, Richard R. Smith Company

Gibson, *Sharp Eyes*, pages 48-51, 240-243 (out of print)

Holman and Robbins, *A Textbook of General Botany* (second edition), pages 87-152, John Wiley and Sons

Mottier, *College Textbook of Botany*, Chapter III, Blakiston's Son and Company

Rigg, *College Botany*, Chapter III, Lea and Febiger

Robbins and Rickett, *Botany*, Chapter IV, D. Van Nostrand and Company

Sinnott, *Botany, Principles and Problems*, pages 88-116, McGraw Hill Publishing Company

Smith (and others), *A Textbook of General Botany*, pages 25-41, The Macmillan Company

Snyder, *General Science*, page 188, Allyn and Bacon

Torrey, Ray E., *General Botany for Colleges*, Chapter IV, The Century Company

Transeau, *General Botany*, pages 105-176, World Book Company

CHAPTER XIX

THE ROOT — THE PLANT'S ABSORBING ORGAN AND ANCHOR

*The tree of deepest root is found
Least willing still to quit the ground.*

— HESTER L. THRALE

201. The Hidden Parts of a Plant. — In spite of the importance to man of the stem of a plant, it is upon the roots that the plant depends for its success in manufacturing food, especially starch. This is

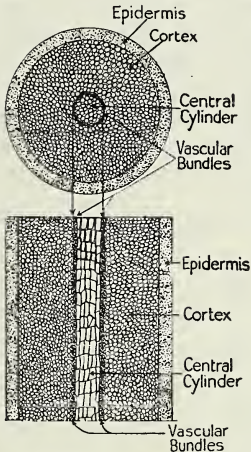


FIGURE 227. CROSS AND LONGITUDINAL SECTIONS OF A ROOT

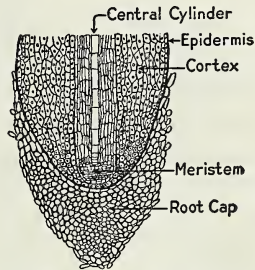


FIGURE 228. VERTICAL SECTION OF A ROOT TIP

In what respects does meristem resemble cambium?

because the roots are the organs that gather water from the soil. Water containing substances in solution is the chief raw material used by the leaves in making starch ; hence, two factors regulating its supply are of the greatest importance. One is the soil itself as the reservoir for moisture, and the other is the roots which gather that moisture.

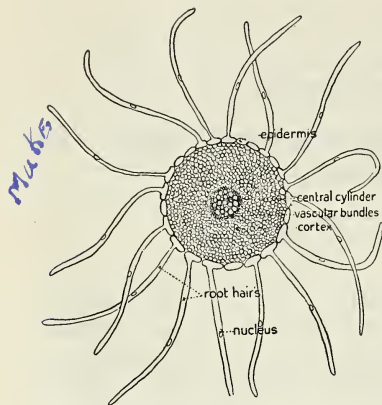


FIGURE 229. CROSS SECTION OF A YOUNG ROOT WITH ROOT HAIRS

These were grown in moist air. How do they differ from those grown in soil? Why?

to the stem and digested food back to the root. Near the tip is the main growing region from which the epidermis, the cortex, and the central cylinder are formed. Covering the tip of the root is a *root cap* which protects the end of the root from injury as it pushes through the soil.

Besides the main root, there are many smaller roots which divide still further into rootlets. The small secondary roots branching from the main roots start from the central cylinder. The root and its divisions underground may be compared, in a general way, to the stem, branches, and twigs above ground.

A second important use of the roots is to hold the plant securely in place. To accomplish these two ends, many plants have a system of roots larger than the parts that grow above ground.

202. Structure and Functions of Roots. — The outer part of the root is covered with an *epidermis* which acts as a protective layer and keeps the root from drying. Inside this is a region called the *cortex* where most of the food is stored. The cortex surrounds the *central cylinder*, containing the vessels that carry water

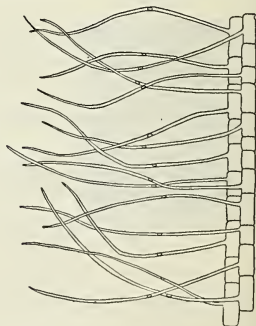


FIGURE 230. EPIDERMIS OF A ROOT WITH ROOT HAIRS

Does every cell produce a root hair?



1. Tap
(Dandelion)



2. Fibrous
(Grass)



3. Thickened fibrous
(Buttercup)



4. Tap
(Beet)



5. Fascicled
(Dahlia)



6. Prop
(Corn)



7. Aquatic
(Duckweed)



8. Climbing
(Trumpet creeper)



9. Aërial
(Orchid)



10. Parasitic
(Dodder)



11. Symbiotic
(Nodules on roots)

FIGURE 231. ROOTS

Root Hairs. — Root hairs are found a short distance back from the tip of each rootlet. Each hair consists of a projection of an epidermal cell. Root hairs are very numerous. As the root grows, the hairs farthest from the tip die and are replaced by new ones nearer the tip. Root hairs greatly increase the absorbing surface of a rootlet. They attach themselves firmly to particles of soil from which they take almost every trace of moisture by osmosis. (See page 43.) They also serve to fix the plant firmly in the soil.

LABORATORY STUDY OF ROOTS

Cut a root of carrot or parsnip lengthwise and identify (1) the *epidermis*; (2) the *cortex*, the region under the epidermis; and (3) the *central cylinder*. Cut it crosswise and identify the same regions. Make drawings of both sections and label fully. In both sections look for rootlets and note the region from which they arise. Show this in your drawing.

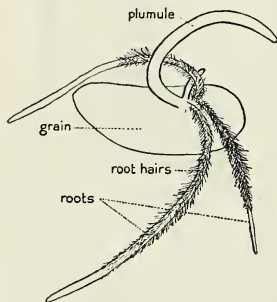


FIGURE 232. GERMINATING WHEAT SHOWING ROOT HAIRS

This grain of wheat was germinated in moist air and not in soil. It is difficult to find root hairs on roots that have been pulled from the soil. Why?

Adventitious roots grow from stems or leaves, especially those that grow freely when the cutting of a stem is put in water or moist soil (§ 197). Such garden plants as tomato, cucumber, squash, and others, put forth adventitious roots where their stems touch the soil, especially at the nodes in the case of the vines

203. Some Kinds of Roots. — *Knees* are upward projections on roots. The cypress tree, which grows with its roots submerged, has these projections, which extend above the surface of the water. They are so modified that the roots are enabled to secure the air they need.

Stolon roots first appear in the air on the ends of stems or runners, as in the strawberry. After they take root in the ground, they develop like normal roots.

named. This is an adaptation which gives them a greater supply of raw material near the leaves which use it, and which enables that part of the plant to live even if it is broken from the main portion of the stem.

Certain cactus plants which live in the desert have roots twenty times as long as the parts that appear above the soil. This enables them to absorb and to store up the scanty moisture.

204. Duration of Roots.

— Roots that live for only one season are called *annual* roots, examples of which are corn, peas, beans, and other common garden vegetables.

Those that store the food manufactured one season and use it to produce flowers and fruit the next are called *biennial* roots. The garden furnishes examples of these in the fleshy roots of carrots and beets. Roots that live from year to year, like those of trees or dandelion, are *perennial* roots.

205. Length of Roots. — The root system of a tree growing in fertile soil is about equal to the parts above the ground. An oat plant has a root system the combined length of which is about 154 feet; a wheat plant has single roots 7 feet long; and alfalfa has an enormous root system. A single root of alfalfa may extend more than 20 feet in one direction in a loose soil.

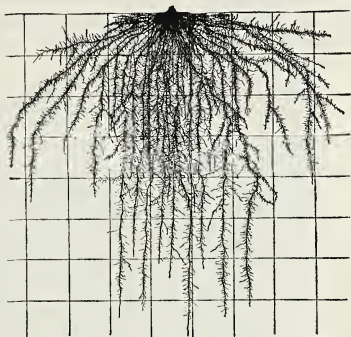


FIGURE 233. ROOT SYSTEM OF CORN

How large a cone of earth do the roots occupy?

LABORATORY STUDY OF ROOTS

Look at the roots of seedlings furnished you. How does the extent of roots compare with the parts above ground?

Examine roots grown in a moist chamber for root hairs. Compare with one grown in sawdust or soil after it has been carefully washed. How do they differ? On what part of the rootlet are the root hairs most numerous? Where are they the longest?

In what direction do roots usually grow? Try to make them grow in some other direction.

Demonstration to Show Region through Which Liquids Rise. — Stand cut-off roots of parsnip overnight in water tinted with red ink. In what region does the color show? Make cross sections of one and longitudinal sections of another.

SUGGESTIONS FOR HOME WORK

Pull weeds and examine the roots. Which have tap roots? Why do they flourish better than the plants around them?

Cut a piece of thick sod with a sharp spade or trowel. How many grass plants are there in a square two inches on a side? What kind of roots has grass? Wash the dirt away carefully and measure the extent of the root system. Compare it with the part above the ground.

On how many nodes of a corn stem do prop roots grow? What is the effect of "hilling up" corn on the production of prop roots?

Place willow twigs in water. Watch the growth of adventitious roots, noting especially the root caps. Do duckweed and other floating plants have root caps? Account for what you find.

Examine a large number of roots and make a report on a table similar to the following. Do not mark your book.

PLANT	ROOTS ALL UNDER-GROUND	ROOTS NOT ALL UNDER-GROUND	PRIMARY ROOTS	FIBROUS ROOTS	AËRIAL ROOTS
Dandelion .					
Plantain .					
Carrot . .					
Dahlia . .					
Corn . .					
Ivy . . .					

206. Economic Uses of Roots. — In some plants the root is the most valuable part for food not only for man but also for his animals. Examples of this are found in many of the garden vegetables. The food stored in the beet is rich in sugar, making it one of the sources of the sugar of commerce as well as a valuable food for stock. Other roots furnish substances used as medicine, as rhubarb and mandrake, while the root of ginger, ground, is used in medicine and in cooking.

In the case of these roots, a few must always be saved to produce seeds for another crop, inasmuch as turnips, beets, carrots, parsnips, and vegetable oysters are biennials, which must be planted the second season, when they use food stored during the first year to produce fruit and seeds.

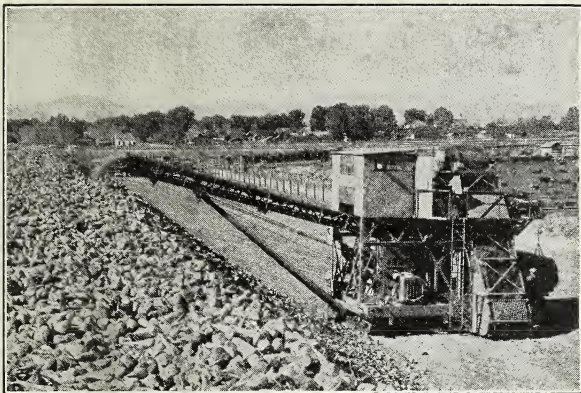


FIGURE 234. A PILE OF SUGAR BEETS
Of what value are these roots to man?

SUMMARY

Only about half of a plant is commonly seen. The stem and leaves above the ground are balanced by a root or root system hidden in the soil. The function of roots is to gather water and raw materials for the plant as a whole, to hold it securely in place, and, in some instances, to store food for it. Roots have many forms, the primary or tap root and the fibrous roots being the extremes. Small roots have a root cap to prevent injury to their tips, and root hairs to increase their absorbing surface. There are specialized roots for special purposes, such as aerial roots for support and for gathering water. Adventitious roots are those that grow on "slips." Roots form an important part of man's food and food for his animals. The root system of a plant is the part that can most easily be affected directly by improving soil conditions. Roots are known as annual, biennial, or perennial. Biennials store food one year to be used the next in producing seeds. These are among our most valuable food plants. The combined length of a root system is often very great.

QUESTIONS

What is the root? What does it do for the plant? Describe the structure of a tap root. How do fibrous roots differ from a tap root? In which kind of roots is the most food stored? What use does the plant make of this stored food? What use does man make of it? What kinds of food are stored in roots?

SPECIAL TOPICS FOR DISCUSSION

1. What food substances are found in roots?
2. What roots are used for medicine?
3. Why does the root of a biennial plant shrink when the flowers are produced?
4. Discuss the relative merits of beets and sugar cane as a source of sugar. Learn how sugar is manufactured from these plants.

REFERENCES

- Bergen and Caldwell, *Introduction to Botany*, pages 20-33, Ginn and Company
 Bergen and Caldwell, *Practical Botany*, pages 5-16, 24-38, Ginn and Company
 Conn, *Biology*, pages 112-114, Silver, Burdett and Company
 Cook, *College Botany*, pages 58-69, J. B. Lippincott Company
 Eyster, *College Botany*, pages 125-130, Richard R. Smith Company
 Holman and Robbins, *A Textbook of General Botany* (second edition), pages 153-180, John Wiley and Sons
 Mottier, *College Textbook of Botany*, Chapter IV, Blakiston's Son and Company
 Rigg, *College Botany*, Chapter IV, Lea and Febiger
 Robbins and Rickett, *Botany*, Chapter III, D. Van Nostrand and Company
 Sinnott, *Botany, Principles and Problems*, pages 40-62, McGraw Hill Publishing Company
 Smith (and others), *A Textbook of General Botany*, pages 16-24, The Macmillan Company
 Torrey, Ray E., *General Botany for Colleges*, Chapter III, The Century Company
 Transeau, *General Botany*, pages 177-202, World Book Company
 Weaver, *Root Development of Field Crops*, McGraw Hill Publishing Company
 Weaver and Bruner, *Root Development of Vegetable Crops*, McGraw Hill Publishing Company

CHAPTER XX

FLOWERS AND FRUITS

*Full blossomed trees,
At once with glowing fruit and flowers crowned.*

— LOWELL

207 The Plant Advertises. — Flowers are the organs that indicate the attempt of the plant to reproduce its kind. The faded flower, which has little interest for us, is usually the sign that the plant has been successful.

The flowers that depend on

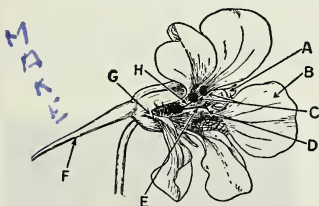


FIGURE 235. NASTURTIIUM FLOWER

A, sepal; B, petal; C, anther; D, stigma; E, style; F, spur; G, ovary; H, filament.

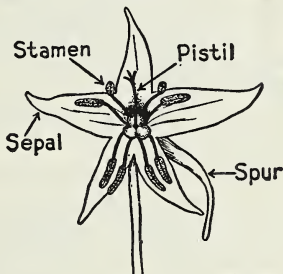


FIGURE 236. FLOWER OF NASTURTIIUM WITH PETALS REMOVED

Note the two forms of stamens. What parts that appear plainly are not named?

wind to help them form seeds are usually more numerous and not so conspicuous as those relying on insects for this work.

After the flower fades, the plant develops not only seeds, each containing a new plant and food for its early life in the soil, but also fruit whose purpose is to protect the seeds for a time and finally to secure their distribution. Unless the flower develops into fruits containing seeds, it has not been of use to the plant which bore it.

208. Parts of a Flower. — The following parts, found in the nasturtium, are common to most flowers :

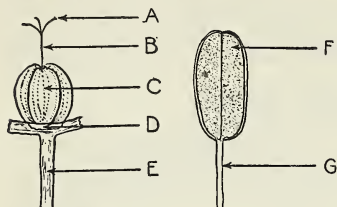


FIGURE 237. PISTIL (left) AND STAMEN (right) OF NASTURTIUM

A, 3-parted stigma; B, style; C, 3-parted ovary; D, receptacle; E, peduncle; F, anther, with pollen; G, filament.

Do all 3-parted stigmas have 3-parted ovaries? Is this stamen young or old? How can you tell?

more showy because more brightly colored, which taken together make up the *corolla*.

Stamens are the slender organs which surround the central portion of the flower. A stamen has two parts, the *filament* or stalk, and the *anther* or box at the top, which contains the pollen.

The *pistil* is the central portion of the nasturtium and consists of three parts. At the top is (1) the *stigma*, below it (2) the *style* which connects the stigma with the lowest part, and (3) the *ovary*.

The sepals and the petals are sometimes spoken of as *accessory parts*, in distinction to the stamens and the pistil, the *essential parts*. Only the latter are nec-

Sepals are greenish, pointed, leaf-like parts on the outside of the flower. Together they make up the *calyx* which protects the rest of the flower, at least while it is in the bud, from insects, cold, rain, etc. When the flower is in full bloom, the calyx is on the lower side, more or less hidden from view. One of the sepals has a *spur*, in the bottom of which is a drop of *nectar*.

Petals are the larger parts,



FIGURE 238. FLOWER OF THE LILY

How does it differ from a violet?
from a columbine?

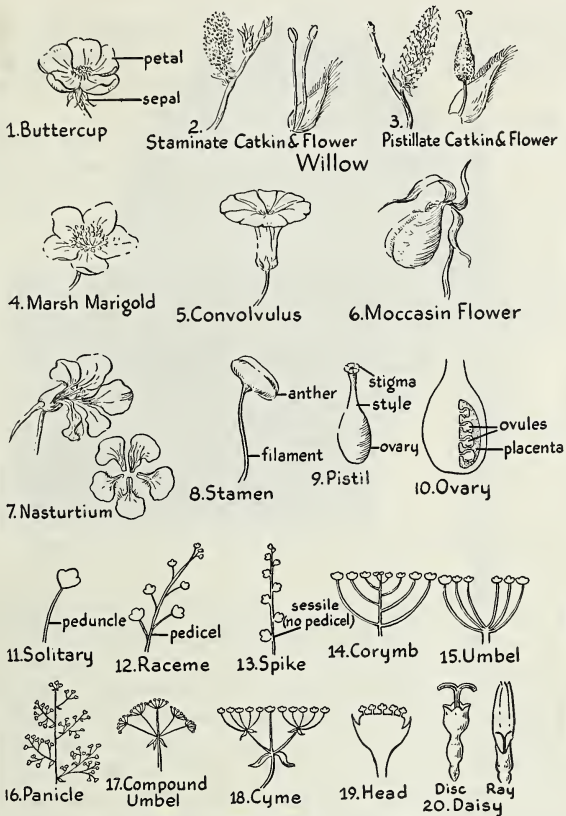


FIGURE 239. INFLORESCENCE

The buttercup is a perfect, complete, regular, radial flower; the willow is imperfect.

The marigold is incomplete, having no corolla; the convolvulus is regular and tubular; the moccasin flower is irregular, bilateral, and has no spur.

The nasturtium is irregular, not tubular, and bilateral, and has a spur.

essary for the production of seeds. The nasturtium is a *perfect* flower because it has the parts necessary for the production of seeds, and it is a *complete* flower because it has also the accessory parts.

Besides the four principal parts found in nasturtium flowers, other parts will be found in certain flowers. The *receptacle*, for example, is the expanded top of the stalk on which the



FIGURE 240. SPIKE OF PLANTAIN

Is self-pollination likely to occur?

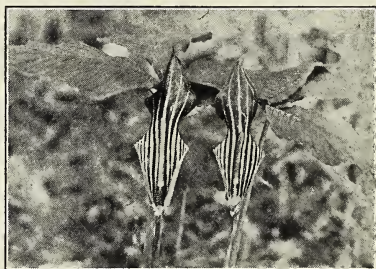
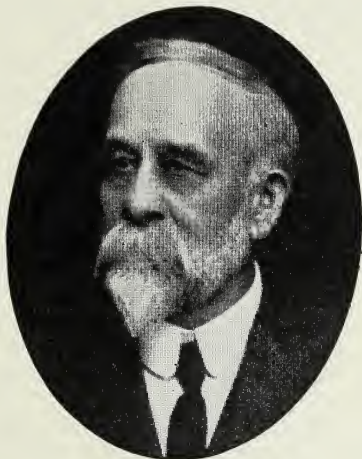


FIGURE 241. JACK-IN-THE-PULPIT FLOWERS

floral organs are placed. This is sometimes oval as in buttercups, or large and fleshy as in strawberries, or hollow as in the rose, where the pistils arise from its inner surface. The *crown* is a projection growing from the surface of a petal as in narcissus. The *spur* already mentioned is another modification of a petal or sepal. Violets, snapdragons, toad flax, and larkspur have spurs. *Nectar glands*, usually found near the base of a flower, are commonly present in those flowers which are adapted to attract insects.

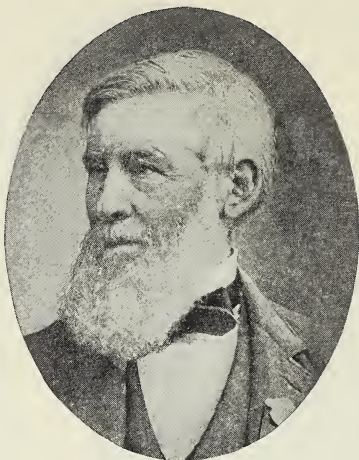
In the lily the six parts of the same color, size, and shape make up the *perianth*. Because of the even size and regular shape of the parts of the perianth of the lily, we speak of it as a *regular* flower. The perianth is an *accessory* part of the flower, for seeds can be



CHARLES EDWIN BESSEY (1845-1915) was born in Milton, Ohio, and died at Lincoln, Nebraska.

He was educated in the country schools and academy, and at the Michigan Agricultural College, from which he graduated in 1869. In February, 1870, he began his duties as professor of botany at the Iowa State College at Ames, Iowa. In addition to botany, he taught zoölogy and entomology for the larger portion of the fifteen years that he remained at that institution. He assumed the professorship of botany at the University of Nebraska in November, 1884, a position held by him until his death.

His greatest contributions to botany are the introduction of the laboratory method in teaching the science, his enrichment of the whole field of botany by teaching many new aspects of the subject, and his profound influence upon students and future investigators.



ASA GRAY (1810-1888), born in Paris, New York, was a man of whom American botanists are justly proud. As a poor boy, he had a hobby, fondness for plants, ambition, and the will to work. As a man, he first earned his living by practicing medicine. On his long rides he collected plants and studied them, and, after a time, gave up his profession and devoted himself passionately to the study of botany. In those days botany was taught only as a division of natural history, even in colleges, for the importance of the subject was not recognized. Through Gray's work and enthusiasm, it was raised to its proper place as a separate science. Besides writing books and training his pupils in Harvard University, where he taught for nearly twenty years, Gray founded the university's Botanical Garden at Cambridge, Massachusetts.

made without it, the stamens and the pistil being the only *essential* parts.

209. Functions of the Parts of a Flower. — The *sepals* are adaptations that protect the inner organs in the bud while they are developing, and the *petals* are adaptations that attract insects which distribute the pollen. Sometimes one set of organs is lacking and sometimes another. Very often, sepals are colored and serve as petals.

The *stamens* produce the pollen without which seed cannot be formed.

In the *ovary*, the expanded base of the pistil, are found the *ovules*, which contain the egg cells and become seeds if fertilized (see Pollination, §§ 210 and 211). The stigma and the style are parts which help to make fertilization possible.

When a flower has finished its work, namely, to secure the fertilization of the egg cells in its ovules, its showy parts, if it had any, wither, and the fruit begins to form.

Usually it is only the ovary which enters into the fruit; but in some cases, the receptacle is included.

Composite Flowers. — This term is applied to flowers in which tiny individual flowers are closely crowded or grouped into a head, on a common receptacle. Such is the dandelion or the daisy, each group being commonly called a flower.

Is this a complete flower? a perfect flower? Compare with the nasturtium.

Two kinds of flowers are to be found in these heads, *tubular flowers*, that is, with the corolla a tube, and *strap-shaped* flowers in which the corolla is long and slender. Some composite flowers, like the dandelion, have only the strap-shaped, and others, like the thistle, only the tubular kind. Still others, like the common daisy and the sunflower, have both kinds. In the daisy, the

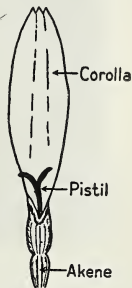


FIGURE 242. RAY FLOWER OF DAISY

Is it perfect? complete? What plants have flowers similar to those of daisy?

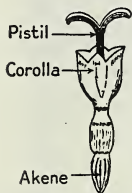


FIGURE 243. DISC FLOWER OF DAISY



FIGURE 244. YUCCA FLOWER AND MOTH

At the left is the flower; in the center, the separated parts; at the right, some yucca moths. What can you find out about the yucca moth?



FIGURE 245. SPIKES OF FOXGLOVE

HOME WORK

Study flowers and record the results, using the following table as a guide. Do not mark your book.

FLOWER	COROLLA REGULAR	COROLLA IRREGU- LAR	COROLLA LACKING	STAMENS ONLY IN A FLOWER	PISTILS ONLY IN A FLOWER	FLOWER PERFECT
Geranium . . .	X					
Castor bean . .						
Salvia		X				
Nasturtium . .						X
Pansy		X				
Etc.						

tubular flowers, found only in the middle, are called *disc flowers*. These make up the yellow part of the group. Outside of them are the white, strap-shaped kind, known as the *ray flowers*. In the sunflower the disc flowers are brown, and the ray flowers yellow.

210. Pollination. — Insects go to a plant in order to get nectar. The plant takes advantage of this by adaptations which help the insect to become covered with pollen as it leaves the flower. Other adaptations bring it about that when the insect enters a flower, some of the pollen from the flower last visited is left on the stigma of the one which it is entering.

This *pollination* is only the first step in the production of seed. Before we can understand the use of pollina-



FIGURE 246. COMPOUND UMBEL OF WILD PARSNIP

The umbel is the characteristic form of inflorescence of a whole family of plants. What common weeds belong to this family?



FIGURE 247. BEES WITH LOADS OF POLLEN ON THEIR HIND LEGS

tion, we must understand the structure of the pollen grain, which is a cell.

Pollen grains present the greatest variety in size, structure, and markings, but all have some features in common. They all have a double coat or covering, the outer side of which is thin in places. When a pollen grain is caught on a sticky stigma, it soon sprouts; that is, the inner coat pushes out through the thin places in the outer coat, producing a tube. This contains the protoplasm of the pollen grain and three nuclei. One of these, the *sperm nucleus*, will unite with the nucleus of the egg in the ovule. The union of a sperm nu-



FIGURE 248. POLLEN GRAIN, SPROUTED

The upper nuclei are male or generative nuclei. The lowest is the one that regulates the activities of the tube itself.

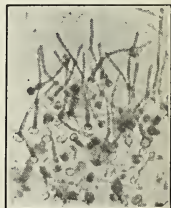


FIGURE 249. PHOTOMICROGRAPH OF POLLEN GRAINS SPROUTING IN A WEAK SOLUTION OF SUGAR

cleus and an egg nucleus is known as fertilization. The fertilized egg cell at once begins to divide in the process of forming a new plant. At the same time, the ovule develops into a seed.

The pollen tube and the style both show adaptations. The style is either tubular, affording a path for the pollen tube, or it is composed of cells very loosely packed, allowing the tube to pass through it readily. The adaptations of

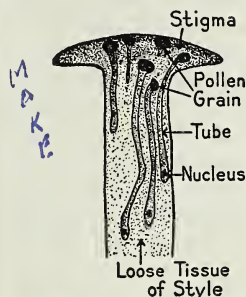


FIGURE 250. POLLEN GRAINS
SPROUTING AND GROWING THROUGH
STYLE

What adaptation of the stigma
helps to hold the grains?

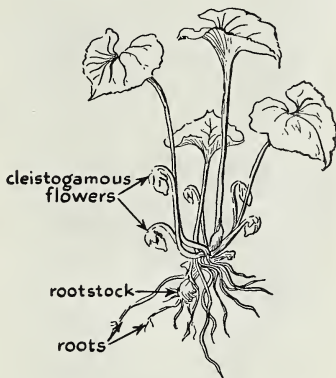


FIGURE 251. VIOLET PLANT WITH CLEISTOG-
AMOUS FLOWERS

These look like buds, as they grow below the surface and never open. Their one or two stamens pollinate the pistil thoroughly. The capsules which develop contain many seeds. They open above ground.

the tube are its ability to absorb food from the tissues through which it passes, and its ability to find the opening of the ovule.

The distribution of pollen is accomplished by insects and by wind more than by other agents. Pollen that is scattered by wind has two adaptations: (1) it is very abundant, for much of it is sure to be lost; (2) it is light, that it may be easily carried. Flowers that are wind-pollinated usually lack odor, color, and floral envelopes (accessory parts), but they have adaptations in the stigmas, which are either plummy or feathery or broad and sticky, the better to catch and hold the pollen grains brought

to them by the wind. Seeds formed as a result of cross-pollination produce a larger number of variations in plants than those which grow from seeds in self-pollinated flowers.

➤ *Self-Pollination.* — Some flowers, like the cleistogamous flowers of the violet (Figure 251), are arranged with a view to securing



FIGURE 252. FLOWERS OF WILLOW

“Willow pussies” are the staminate flowers in their early stage. Do both kinds grow on the same tree?

pistil. For example, in the primrose, an insect that gets pollen from short stamens on its body in one flower leaves it on the short stigma of another flower.

Artificial Pollination. — In artificial pollination, pollen from one flower is carefully transferred by hand to the stigma of another flower of the same kind. Usually this flower had its stamens removed before the pollen was ripe. It must be protected from the visits of insects after it has been pollinated artificially.

self-pollination. Most flowers, on the other hand, have adaptations to prevent it.

One of these devices is the production of pistillate flowers only on one plant and of staminate flowers only on another plant. The willow illustrates this. A second adaptation is the maturing of the pistil first and the stamens later, as in the case of the plantain, or the maturing of the stamens first and the pistils later, as in the case of the dandelion. A third device is long stamens and a short pistil, or short stamens and a long pistil. When an insect visits such a flower, one part of its body is apt to come into contact with the stamens and another with the

Artificial pollination is practiced to develop new varieties of flowers, fruits (see § 12), and cereals (see § 288).

It was formerly thought that cross-pollination was necessary to produce vigorous plants. Its chief value seems, however, to be to produce variations.

211. Adaptations for Pollination. — The flower of the *nasturtium* offers a good example of adaptations. You will notice that (1) it has a striking color in contrast with the foliage. This enables insects to see it readily. (2) It has an odor. This enables insects that are guided largely by the sense of smell to find it. (3) It has a long nectar spur on one side of the flower. This attracts the larger insects for the food they can get. (4) The lower petals have an inner fringe which retards the crawling insects that are trying to get the nectar. (5) The upper petals project over the other parts of the flower. This keeps the rain from running down the nectar spur and prevents the pollen from becoming wet. (6) The upper petals have stripes that lead to the opening of the nectar spur. This indicates the direction that insects should travel to find the opening quickly. (7) The anthers mature at



FIGURE 253. STAMINATE (TASSEL) AND PISTILLATE (SILKS) FLOWERS OF CORN

Each silk is a long pistil, one to each grain of corn. How long a tube must a pollen grain produce to reach the egg cell?

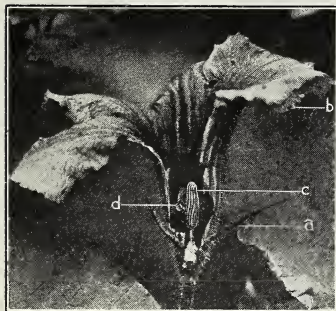


FIGURE 254. FLOWER OF SQUASH PLANT
a, sepal; b, corolla; c, pistil; d, bee.

insects that are trying to get the nectar. (5) The upper petals project over the other parts of the flower. This keeps the rain from running down the nectar spur and prevents the pollen from becoming wet. (6) The upper petals have stripes that lead to the opening of the nectar spur. This indicates the direction that insects should travel to find the opening quickly. (7) The anthers mature at

different times. This insures a supply of pollen on different days so that some of the pollen is in condition to use, even if

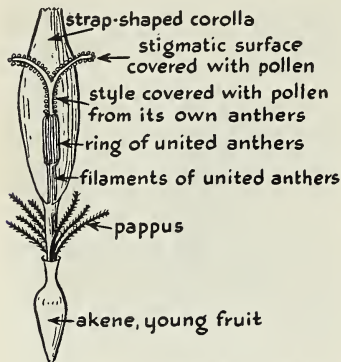


FIGURE 255. FLOWER OF DANDELION

Is it a perfect flower? a complete flower?

some has been spoiled by unfavorable weather. (8) The anthers and stigma mature at different times so that the pollen cannot get on its own stigma. Thus, in at least eight ways the nasturtium flower is adapted to the visits of insects and to the protection of its pollen and nectar.

mature their pollen before the pistil of that flower is ready for pollen. The pistil, with its stigmatic surfaces pressed tightly together, pushes up through the mass of pollen filling the tube, becoming covered on the *outside*. Insects crawling over the head drag some of these pollen grains to pistils which are mature. When the pistil of any one flower expands, its own pollen is not likely to get on it, thus preventing self-pollination of the dandelion flower.

These adaptations of the flowers help to make the dandelion one of the most successful of plants.

Dandelion flowers have many adaptations. The stamens are joined in a tube with the anthers opening on the inside. The anthers ma-



FIGURE 256. FLOWER OF COLUMBINE

The petals are spurred. Note the bunch of stamens, a convenient place for insects to alight. Which would have better success in getting the nectar in the ends of the spurs, a butterfly or a bee?

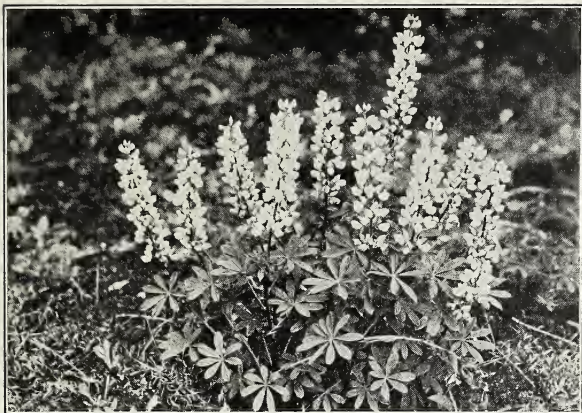


FIGURE 257. BLUE LUPINE

This is a wild member of the pea family. It is not readily transplanted but will grow from seed. Describe the leaves.

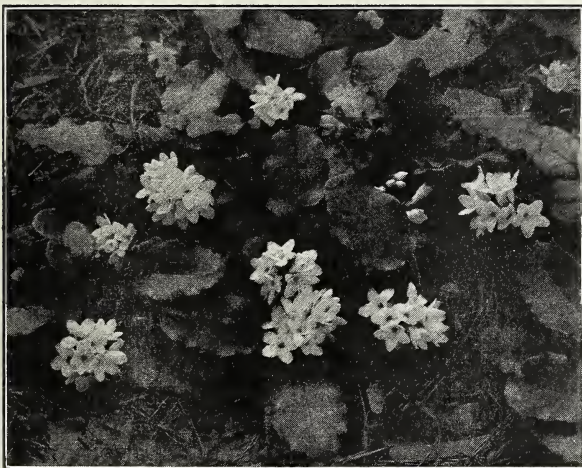


FIGURE 258. TRAILING ARBUTUS

This flower is rapidly becoming rare through the carelessness of those who pick it.

SUGGESTIONS FOR HOME WORK

As soon as flowers appear, observe them closely and note which have many insect visitors and which have few or none. Fill out a report as suggested below and add any points that interest you besides those mentioned. Do not mark your book.

FLOWER	COLOR CONSPICUOUS	COLOR NOT CONSPICUOUS	ODOR STRONG	ODOR NOT STRONG	NECTAR ABUNDANT	NECTAR NOT ABUNDANT	INSECTS MANY	INSECTS FEW	ETC.
Sweet Pea .									
Dandelion .									
Hepatica .									
Buttercup .									

The composites as a whole show more adaptations than other flowers, so we find among them those that are of most interest to the scientist and those that are of greatest annoyance to the farmer, — dandelion, devil's-paint-brush, burdock, and thistles of all kinds. They are most successfully fought by not giving them opportunity to blossom and form fruit.

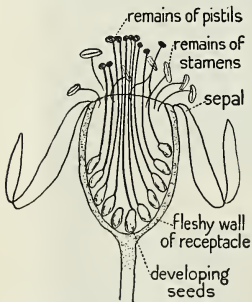


FIGURE 259. DIAGRAM OF FRUIT OF ROSE

How does it differ from the fruit of the apple? the plum?

212. Conservation of Wild Flowers. — We know the pleasure which our wild flowers give all lovers of nature. We are coming to feel that animals and plants which give us pleasure should be permitted to live. Game laws and animal preserves are helping to protect some of our rare animals that were being destroyed by man.



1. Grain
(Wheat)



2. Nut
(Acorn)



3. Akene
(Buttercup)



4. Pod
(Pea)



5. Capsule
(Poppy)

Dry Fruits



1. Pome
(Apple)



2. Drupe
(Peach)



3. Berry
(Orange)

Fleshy Fruits



Violet

1. Dehiscent (opening)



Milkweed



Chestnut

2. Indehiscent (non-opening)



Corn

Dehiscence



Dandelion



Maple



Burdock



Sticktight

1. Wind

2. Animal

Distribution

FIGURE 260. FRUITS

For many years flower protection organizations have been urging that the rarer wild flowers should be protected by law.

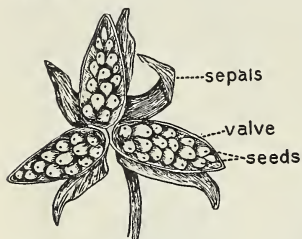


FIGURE 261. CAPSULE OF VIOLET

The shiny seeds are squeezed out of the elastic tissues under them as it dries. How are the seeds adapted by their shape to be shot out? What is the shape of other seeds scattered by elastic tissue, as wild cucumber and witch-hazel?

pick *arbutus* blossoms without pulling up the long trailing stem, which then dies. Picking the flowers of *dogwood* destroys the attractiveness of this tree.

Since the seeds of the plant are developed in the flower, if you pick all the flowers, no seeds can be formed. Lovers of wild flowers are coming more and more to enjoy them where they grow instead of picking them to decorate their homes, where they last not more than a day or two.

213. Nature of Fruits. — The fruit of a plant is the final result of the work of the flower. In its simplest form it is the ripened ovary and its contents, including the seed or seeds. In some cases, however, it involves accessory parts of the flower as well, especially the receptacle. To many, the word *fruit* means orange,

You should do your part in helping to make any such legislation effective.

Because of the scarcity of wild tracts of land, particularly near cities, wild flowers will soon disappear unless the public is educated to enjoy them as they grow without picking them. Little harm is done by picking the flowers of *trillium*, because its thickened stem, deep in the ground, will put up another flower stalk the next year, if it has food enough stored away to enable it to do so. But it is difficult to

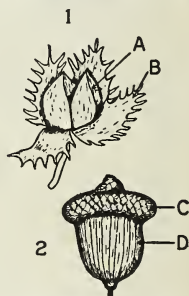


FIGURE 262. DRY FRUITS

1, beechnut; 2, acorn; A, the "nut" (a seed); B, bur (the fruit); C, cup; D, seed. Name the parts of these fruits.



WILD MOCCASIN FLOWER.

This beautiful plant is in danger of becoming extinct through ruthless picking.

apple, or some other common article of food. In biology, however, there are many plant products classified as fruits which are not edible by man, although some are eaten with relish by squirrels, birds, and other animals. Roots, stems, leaves, and flowers have all worked to produce fruit, the highest and sometimes the final work of a plant.

214. Functions of Fruits. —

The vital part of any fruit is the seeds contained inside.

The rest of the fruit is intended by the plant merely to serve the seeds.

It does this in two ways: (1) in protecting the seeds during their development, as in the bean, or during their period of dormancy, as in the nut, and (2) in helping to distribute the seeds after they are matured.

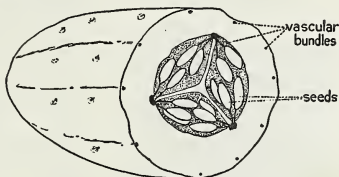


FIGURE 263. CROSS SECTION OF CUCUMBER

What plants have similar fruits?

LABORATORY STUDY

Study of an Orange. — Examine the stem end and note the remains of the calyx. Remove it. How many sepals had the flower? How many

dots do you see? These represent the ends of the vascular bundles which supplied food to the growing fruit. Examine the opposite end for a scar showing where the pistil was attached. Scrape the skin or pinch it, and note the oil which shows as a yellow, odorous liquid.

Make a cross section through the middle of the orange. How many distinct parts are there? Where are the seeds? Note the oil glands in the cut skin. Draw and label the parts named above.

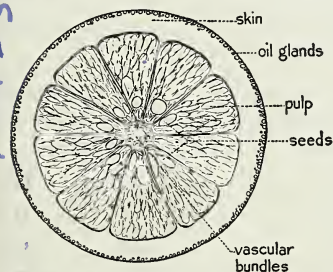


FIGURE 264. CROSS SECTION OF ORANGE

How many sections does it contain?

Remove the skin from a whole orange and separate the parts. How many are there? Look for a strand of conductive tissue on each one. Where does it come from? Compare the number of sections with the number of vascular bundles on the stem end.

Study of a Tomato. — (Canned, unpeeled tomatoes will serve.) Examine the whole fruit for traces of parts of the flower. On which end are they found? How many sepals were there in the flower? Remove the stem and count the number of vascular bundles. Make a cross section through the middle. How many divisions are there in the tomato? Where are the seeds? Can you see the vascular bundle which entered the seed? Note the very thin skin. The tomato is a *berry*. Compare grape, another *berry*, and peach, plum, and cherry, *drupes*.

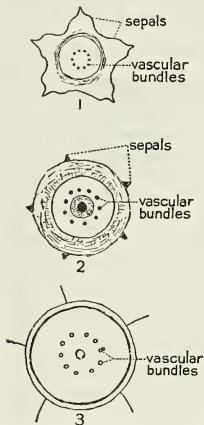


FIGURE 265. STEM ATTACHMENT OF ORANGE

1, green part where stem was attached; 2, under side of the same; 3, pit in orange left when part of stem was removed. How does the number of vascular bundles compare with the number of sections in the orange?

function, a fruit must scatter the seeds it contains. This is necessary for three reasons: (1) the seedlings would choke one another if all were dropped near together; (2) there would be too slow growth, for the soil near the parent might be depleted and the new plants could not grow so well there as in fresher soil; and

(3) the seeds would be scattered by the wind or animals. The tomato is a *berry*. Compare grape, another *berry*, and peach, plum, and cherry, *drupes*.

Study of an Apple. — Examine the whole apple. On the blossom end find the old sepals. How many are there? In the end of the stem look for vascular bundles. Draw and label. Make a cross section through the middle. Draw. Label the seeds in the papery pod (core). How many divisions has it? How many vascular bundles are there, as shown by dots near the core?

Make a vertical section. Label the vascular bundles you see, the stem, the fleshy wall of the receptacle, and the remains of sepals. Are the remains of sepals on the same end in the apple as in the orange?

See how many kinds of fruits you can find. Make a list of fruits obtained.

215. Adaptations of Fruits and Seeds for Dispersal. — In order to fulfill its

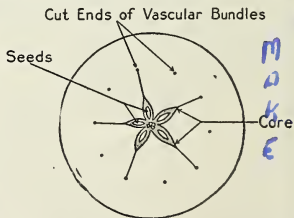


FIGURE 266. CROSS SECTION OF APPLE

(3) there would be too great a chance of extermination if all were dropped near together, for some one unfavorable condition might kill them all.



FIGURE 267. AKENE
OF DANDELION

How is it distributed?

In order to scatter seeds a plant makes use of wind, animals, and water as distributing agents, and of such mechanical devices as exploding pods. To be distributed by the wind, a seed or a fruit must be light. This is brought about in some plants by plumes, as in the case of the dandelion and thistle, by tufts of hairs on the clematis, by the down on a milkweed seed, and by the wings on the fruits of the maple and elm. (Review § 16.) Special devices for wind distribution are found in the Russian thistle and in tickle grass, a common garden weed. In the former case the whole plant breaks off at the level of the ground, and is blown about by the wind, fruits and seeds being broken off and scattered as it rolls along the ground.

For distribution by animals, fruits have adaptation of two kinds — they have hooks for attaching themselves to an animal or they are edible. The burdock and beggar's-tick represent the first kind of adaptation, and the fleshy fruits the second. The adaptations of fleshy fruits are (1) a sour or bitter taste during development. This prevents their being eaten before the seeds are mature. (2) Edibility when ripe; this insures their being

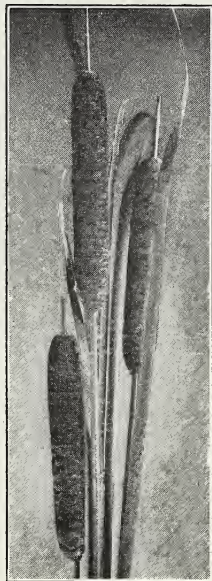


FIGURE 268. CAT-TAILS

Staminate flowers grew on the slender tip in the spring. The brown "cat-tails" are made up of thousands of fruits adapted to wind distribution. What two qualities would you expect this fruit to possess?

eaten by some animal. Sometimes they are eaten without the seeds, which are likely to be dropped some distance from the plant that produced them; sometimes they are eaten with the seeds, in which case the undigested seeds are passed off with other wastes, often very far from the parent plant.

For distribution by water, the adaptations must insure buoyancy and the ability to withstand decay. Both are well illustrated by the coconut, and the former by the cocklebur.

To distribute seeds by forcibly expelling them, dry fruits must have elastic tissue. Take the bean, for example. The pod is elastic. When it dries, it splits and curls up, throwing the seeds out by force. Another elastic pod is the wild cucumber, which forces its seeds out violently as does the pod of the jewelweed, which requires only a touch to set it off, scattering the seeds far and near.

Although plants have other means of propagating themselves



FIGURE 269. FRUIT OF AVENS (BEGGAR'S-TICKS)

What other names do you know for fruits of this kind?



FIGURE 270. FRUIT OF HOUND'S-TONGUE

A "stick-tight." What other fruits are covered with small projections?

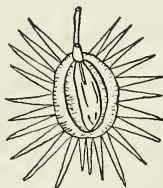


FIGURE 271. FRUIT OF WILD CARROT

It is light and the projections adhere easily. What agents are most likely to distribute it?



FIGURE 272. CLOT-BUR OR COCKLEBUR

This is both hooked and buoyant. In what ways may it be distributed?

(see §§ 197 and 203), the main dependence for keeping up the race in most plants, especially the wild ones, is the distribution of the seeds.

216. Economic Value of Flowers. — Many plants are cultivated for the pleasure their flowers give us. The vocation of florist has become a rather profitable one.

Cauliflower, the buds of which are eaten, is the most familiar example of the use of flowers for food.

A few flowers are used for medicine, though not so many now as formerly. Among them may be mentioned dandelion, the elder, the mullein, and camomile.

Saffron, a yellow coloring matter, is obtained from the stigmas of the saffron crocus.



FIGURE 273. JEWELWEED

This explosive pod ejects its seeds with force. What other fruits disperse their seeds in a similar way?

HOME WORK

Examine florists' and gardeners' catalogues, and note the plants the flowers of which are used as food and for ornament. Read about the use of hops and the process of raising and harvesting them.

217. Economic Value of Fruits. — In many plants, the fruit is the part of greatest use to man, furnishing him most of the necessities in the way of food, and many of the luxuries.

In speaking of the uses of fruits to man, it must be remembered that in biology all grains are fruits and that many so-called vegetables are fruits, as the tomato, squash, and cucumber.

The most valuable and dependable source of food in the world is found in the cereals: wheat, corn, oats, rye, rice, barley, and others. Nearly half of the population of the globe depends on rice as its principal food.

Not only are the cereals the most important article of food, but they are the basis of a great part of the world's work. The raising of cereals, their preparation for food, and their distribution give employment to a greater number of persons than any other industry. (See Figures 29, 30, 274, and 441.) More attention is



FIGURE 274. AN HAWAIIAN RICE FIELD

What other fruits do you see here?

now given to agricultural education than formerly, because agriculture as an industry is now better appreciated. Besides supplying man with food directly, many cereals are used to feed the animals which are raised for their meat, milk, butter, cheese, and eggs.

The articles of food commonly known as fruits, — apples, oranges, berries, bananas, and others, — are very valuable, their chief use being to supply vitamins (see § 361) and flavor in the diet.

The fruits obtained from

the vegetable garden, — tomatoes, cucumbers, squashes, eggplant, melons, and others, — furnish a welcome variety of foodstuffs.

It will be evident by this time that the words *fruit*, *seed*, and *nut* do not have the same meanings in biology as in ordinary speech. The terms “seed corn” and “seed wheat” used by farmers are correct in the sense that they indicate the corn and the wheat which are planted or sowed to produce new crops. The so-called Brazil nut of commerce is in reality a seed. The fig is a “fruit” composed of a thickened and hollow receptacle, the end of a branch, on the inside of which are produced the real fruits commonly known as seeds.

HOME WORK

Cereals. — What articles of food on your breakfast table are cereals? Where were they raised? How were they brought to your home? What kinds of food were furnished by each? Look up the population of China, India, and Japan for the year 1930 or later. Most of these people live chiefly on rice. How does their number compare with those in the northern countries of Europe and the United States who live largely on the other cereals?

Fruit Growing in the United States. — The raising of fruit is one of the large industries of the United States. The Great Lakes region, especially the shores of Lakes Erie and Ontario, is famous for grapes, apples, peaches, plums, and cherries. California produces large crops of oranges, grapefruit, lemons, prunes, figs, and grapes. Florida has long been noted for its oranges and grapefruit. Oregon, Washington, New Hampshire, and Virginia produce large crops of apples. Each kind of fruit thrives best in a special kind of soil and certain conditions of climate, and each has its own particular enemies. Look up the enemies of the apple tree. How is each combated? How does the life history of the codling moth differ in eastern states and western states (New York and Oregon)? How is danger to orange groves from frost avoided in Florida and California? How is moisture supplied in Oregon and Washington? What kinds of birds are especially helpful in orchards? Why? What insect is helpful in the orange groves of California? Learn the history of it in this country.

What are the advantages of dynamiting the soil in setting out trees? How was the loganberry produced? How does grape juice differ from wine? Why is it necessary to prune vines and trees? Look up the history of grapefruit. How do navel oranges differ from others? Look up their history.

SUMMARY

Flowers are the organs of the plant which provide for the production of seed and thus continue the race. The pistil and stamens are the essential parts of the flower. Colors, odors, and nectar are devices for attracting insects that bring about cross-pollination. Wind-pollinated flowers are usually inconspicuous, and they have an abundance of light pollen. The pollen grain is a cell which contains the sperm nucleus. This is carried to the egg cell in the ovule by a tube. The union of the two nuclei of these cells is fertilization. The fertilized egg cell develops into an embryo plant, and the ovule develops into a seed which protects the embryo and contains food for its early life.

The fruit contains the seeds. It develops from the ovary of the flower. Fruits are distributed by animals, by wind, and by water, and each kind

has special adaptations to accomplish its end. Dispersal is necessary to give the new plants a better chance to grow. Fruits are of the greatest use to man as food.

QUESTIONS

What is the function of flowers? What are the essential organs of a flower? What devices have flowers for attracting insects? What devices have they for wind pollination? What is the pollen grain? the ovule? What is fertilization? In what does it result? What is a fruit? What purpose does it serve? How? What kinds of fruit are there? Describe a grape; a peach; a raspberry. Of what use is the fruit to man? How are fruits distributed? Why is dispersal necessary?

SPECIAL TOPICS FOR DISCUSSION

1. Make a list of flowers that are used for dyeing; for medicine; for perfume.
2. Read about plants that are raised by the acre for their flowers, as callas, peonies, asters, lilies, etc.
3. Make a study of the native homes of plants that we now cultivate for their beauty.
4. Learn how perfumes are made: essences; extracts; decoctions.
5. What wild plants that grow in your vicinity would make pretty garden plants?
6. What plants formerly grown in gardens have escaped from cultivation? How do they compare with the cultivated specimens?
7. Have insects any preference as to the color of flowers?
8. What kinds of insects have you noticed around flowers? What were they doing there?
9. What kinds of flowers attract humming birds? What do they get from them?
10. Make a list of plants which we cultivate for their fruits.
11. What are nutmegs? cloves? Brazil nuts? horse-chestnuts? figs? What is mace? pepper? coffee?

REFERENCES

- Bergen and Caldwell, *Introduction to Botany*, pages 125-157, Ginn and Company
Bergen and Caldwell, *Practical Botany*, pages 104-135, Ginn and Company
Bessey, *College Botany* (1914), pages 285, 302-313, 321-324, Henry Holt and Company
Conn, *Biology*, pages 118-125, Silver, Burdett and Company

- Cook, *College Botany*, pages 82-116, J. B. Lippincott Company
- Coulter, *Plant Life and Plant Uses*, pages 58-61, 258-321, D. Appleton and Company
- Gibson, *Sharp Eyes*, page 115, Bar and Hopkins
- Holman and Robbins, *A Textbook of General Botany* (second edition), pages 234-308, John Wiley and Sons
- Rigg, *College Botany*, Chapters V and VII, Lea and Febiger
- Sinnott, *Botany, Principles and Problems*, pages 184-199, McGraw-Hill Publishing Company
- Smith (and others), *A Textbook of General Botany*, pages 273-280, 313-327, The Macmillan Company
- Snyder, *General Science*, pages 395-434, The Macmillan Company
- Torrey, Ray E., *General Botany for Colleges*, Chapters VI and VII, The Century Company
- Transeau, *General Botany*, pages 232-271, World Book Company

CHAPTER XXI

THE SEED — HOW A FLOWERING PLANT BEGINS LIFE

The beginnings of all things are small.

— CICERO

218. Beginnings. — It is natural for one to think of the life of a plant as beginning with the sprouting of the seed. As a matter of fact, however, it began when the young plant was formed in the seed, which may have taken place months or even years before the seed sprouted. Many of the characteristics of the new plant were determined before it began to sprout, since they were inherited from its ancestors. Some of its characteristics will be determined by the conditions under which it grows. A plant, to be successful, must inherit good characteristics, and it

must also have suitable conditions under which to develop.

To man, fruit usually suggests something good to eat. To the plants which produce them, fruits are necessary to secure the distribution of their seeds.

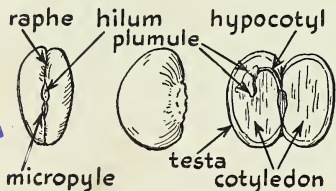


FIGURE 275. BEAN SEED SHOWING PARTS

What is an embryo? Are all seeds alike?

(*ovule*) consists of a mass of tissue (*nucellus*) in one part of which (*embryo sac*) lies the egg cell. The ovule is covered by two coats (*integuments*). It is attached to the fruit by a stalk through which it gets its nourishment. The integuments do not quite meet at one point, leaving an opening (*micropyle*) through which the pollen tube usually enters.

As the ovule develops into a seed several changes occur. (1) The coverings (*integuments*) become firm and hard, the

219. The Bean from Ovule to Seed. — A very young seed

outer forming the testa. (2) The egg cell divides many times, forming the embryo which consists of the following parts: (a) *two cotyledons*, (b) the *stem tip* or *plumule*, often with leaves fairly well developed, (c) the *hypocotyl*, the lower part of which will form the root. (3) The stalk drops off, leaving on the bean seed a scar, the *hilum*.

220. Adaptations of the Seed.—The bean seed is adapted to fulfill the purpose of providing for a new bean plant in the following

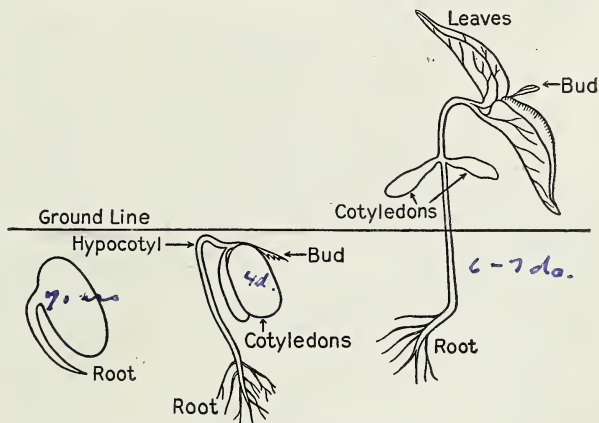


FIGURE 276. EARLY GROWTH OF BEAN PLANT

Left, root free; center, root branched, hypocotyl developed and showing the arch; right, young bean plant. Note the shriveled cotyledons and the first true leaves. How does the corn plant begin to grow?

ways. (1) A ripe seed contains a young plant well started. (2) It can resume growth soon after being formed, or it can remain dormant for years. This dormancy may prevent total loss of seed. (3) It is surrounded by a hard testa which prevents the embryo from drying out during a long resting period. (4) It can absorb water slowly through the micropyle when covered with moist earth. This softens the testa and causes the cotyledons to swell, helping to release the entire embryo. (5) The cotyledons

of the embryo supply its food till it can make its own. This insures rapid growth in the early stages, an advantage in competition with other seedlings.

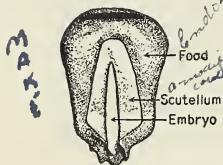


FIGURE 277. UN-
SPROUTED GRAIN OF
CORN

The corn embryo has only one cotyledon, the scutellum.

All seeds are like that of the bean in having a firm covering, and in having an embryo plant inside well supplied with food for its early growth. However, there is great variety in their size, shape, and manner of developing.

221. Development of the Bean Embryo. —

The first step in the growth of the young plant takes place when the root first breaks out of the testa. This is an adaptation, for it at once begins to absorb water needed for further growth and soon becomes firmly embedded in the soil. This primary root is followed later by secondary roots.

The second adaptation is the curving of the hypocotyl. This forms a loop, the top of which is often called the *arch*. The hypocotyl grows rapidly, causing the arch of the loop to turn from side to side, pushing the particles of soil apart and working its way to the surface. Then the cotyledons are pulled up as the arch straightens. Finally, further growth of the hypocotyl causes the cotyledons to spread apart, exposing the *plumule* to the air and light. At the same time the cotyledons begin to turn green, thus serving as leaves till the leaves of the plumule have developed. So the plumule is protected and given a chance to grow under good conditions. As soon as the food in the cotyledons has been absorbed by the young plant, they shrivel and drop off, while the stem and leaves continue to grow. The young bean plant is known as a seedling while it is dependent on the store of food in the seed.

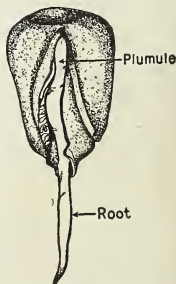


FIGURE 278. PLU-
MULE OF CORN READY
TO BREAK OUT

The root is free and growing downward. What is the advantage in having the root develop first?

In the course of a few weeks a bean plant is large enough to produce blossoms which develop into pods containing seeds, thus completing the life *cycle*.

222. Corn Seed. — A grain or kernel of corn, commonly called a seed, is like a bean (1) in containing a young plant, the corn embryo; (2) in containing food for the use of the embryo when it first begins to grow; and (3) in having marks upon it. On one side of the kernel is a depression beneath which the embryo lies. Above the depression is a slight prominence, the scar which marks the place where one thread of the so-called silks was attached. This is most prominent in pop corn. At the base is a stalk by which the kernel is attached to the cob during its development (Figure 281). Corn differs from the bean in the position of its embryo, which is at one side of the food supply. The latter is called the *endosperm*. Another difference between the two is that the corn has a single modified cotyledon called the *scutellum*, the part of the embryo which digests and absorbs the food stored for its use (Figure 281). The cotyledon of the corn never appears above

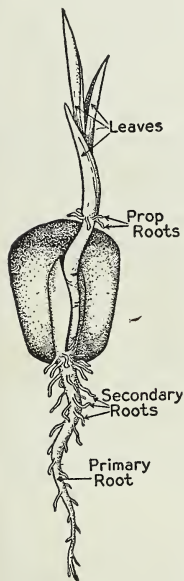


FIGURE 279. PLUMULE OF CORN UNFOLDED

What new features have appeared?

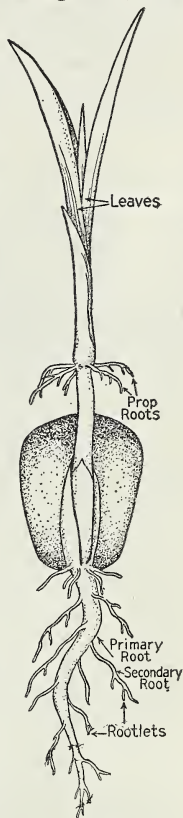


FIGURE 280. . ADVANCED CORN SEEDLING

Compare it with Figure 279.

ground. The corn embryo has its leaves rolled into a tight, pointed bud, the plumule, an adaptation which enables it to pierce the earth above easily. The root is at the lower part of a short hypocotyl.

As the corn has but one cotyledon, it belongs to the class of plants known as monocotyledons. The bean, having two cotyledons, belongs to the class dicotyledons. Review the characteristics of these classes (§ 189).

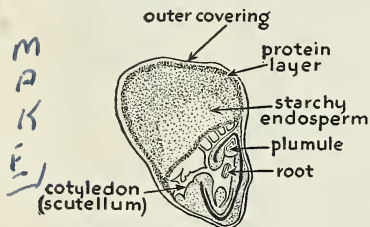


FIGURE 281. DIAGRAM OF GRAIN OF CORN

Compare with the bean.

223. Seeds as Food. — In the bean seed, two kinds of foodstuffs are stored, namely carbohydrates and proteins. Carbohydrate (see page 27) is the foodstuff that includes starch and sugars. Protein (see page 28) is the name given to the foodstuff found in such foods as lean meat,

cheese, and the white of egg, and in animal foods generally. Beans contain more protein than any other seeds.

Corn contains protein, starch, sugar, and oil. Flaxseed and castor beans contain much oil.

In the bean, we shall see that both carbohydrates and proteins are stored in the cotyledons, evenly distributed, so far as we can discover. In the endosperm of a corn grain, the carbohydrates are under the scutellum, and the proteins in a distinct layer outside the carbohydrates, covered by the flinty outside coat of the grain. (See Figure 281.)

LABORATORY WORK

Foodstuffs in the Bean. — The presence of different kinds of foodstuffs may be shown by applying the following (chemical) tests. Boil beans until they are soft and then place a small portion of them in a test tube. Add water. Put in a drop of iodine. If starch is present, the mixture will turn blue. Add strong nitric acid to a second portion in a clean test tube, boil and cool. If protein is present, the mixture will be a clear yellow color which will

become orange if ammonia is added. To a third portion add Fehling's solution (see the footnote on page 43), as a test for sugar. If the latter is present, the mixture will become dull orange when heated. Test uncooked seed for oil (1) by heating it over a lamp on a sheet of linen paper; (2) by soaking it overnight in ether. (This must not be near a flame at any time.) If oil is present, it will show on the paper as a clear spot, and in the second test the oil will appear on the surface of the ether in the test tube.

Test all parts of cotyledons with iodine. Is starch evenly distributed as shown by the blue color?

Remove small portions of the cotyledons from different regions successively and apply the nitric acid test for protein. Do you find that any one region has more protein than another?

Foodstuffs in Corn. — Split kernels in different ways and apply the iodine test. Where is the starch most abundant? *Purple*

Remove the outer layer of a corn grain and apply the nitric acid test. Test the endosperm for protein. What conclusion do you draw as to the position of protein in the seed? *Brown*

Test all portions for sugar, including the embryo. *yellow-red* Where do you find the most sugar? Test all parts of a corn grain for oil, using both tests suggested. In what parts is oil most abundant?

Repeat these experiments with castor bean, Brazil nut, etc., and record the results of each test.

To Show That Seeds Contain Water. — Weigh some squash seeds very carefully after they have been peeled. Place them in a thin dish over a hot radiator for a few hours, then weigh again. Repeat the experiment, using other fleshy seeds. What do you learn from this experiment about the use of the testa to a seed?

To Show That Seeds Contain Mineral Matter. — Burn seeds to ashes in a crucible over a hot flame. What became of the carbon? What became of the water? What else was in the seed? Account for changes of form. What life process of the embryo uses carbon in the same way?

224. Digestion of the Food in the Seed. — It may appear strange that the growing bean seedling lives upon the food stored in the cotyledons, and yet such is the case. This food, however, must undergo a real digestion before the bean embryo can use it. We do not know just how this digestion takes place in the bean, but in the corn, as we have learned, there is a special structure, the scutellum, which helps to digest the food in the endosperm. Digested food is absorbed by the cells by osmosis, and passed into the phloem vessels, through which it is distributed to all parts of the plant.

List Importance...
225. Economic Importance of Seeds. — The use of seeds to a plant is simply to provide for other plants of the same kind, and to insure a supply of food for the early life of each. Man, however, has learned to take advantage of this habit of plants, to secure food for himself and his animals. He has also found ways of enabling the plant under cultivation to store up more food than it could do in the natural state.

*Ewing Galloway*

FIGURE 282. SOY BEANS AWAITING SHIPMENT
Of what importance are these beans ?

In thinking of the seeds used as food, we must limit the term *seed* to its biological meaning. Many articles of food, such as the cereal grains, are commonly thought of as seeds when they are really fruits. Their use as food has already been discussed. (See § 217.) The real seeds that are of greatest use to man as food are those of the pulse family, especially beans and peas, which alone are the source of most of the protein that is obtained from plants. The soy bean introduced from Asia is very valuable. Mature peas and beans contain more food matter than

do "green peas" and "string beans," the latter being valuable more for the bulk they furnish than for their food content.

Besides their use as food, seeds can be used as medicine, castor oil and mustard being common remedies that are obtained from seeds. Castor oil is also used as a lubricant in airplanes because it is not affected by the cold of high altitudes. Two valuable products are obtained from cotton seeds: one, the oil which is used in preparing foods in place of lard and butter and also in packing foods, as sardines; the other, thread and cloth which are made from the fibers covering the outside of the seeds. The fibers are removed by a process called *ginning*; then the seeds are pressed to remove the oil. The refuse forms a valuable food for cattle, especially when mixed with other foods. The length of the fibers varies on different species of cotton, and the uses which are made of the fibers depend on their length.

Linseed oil is obtained from the seeds of the flax plant. It is used in making paint and other substances. After the oil is pressed out, a substance known as linseed cake is left. This is used as food for cattle.

SUMMARY

Plants have for their aim in life the production and distribution of seeds. To do this effectively, they must come from good stock and have good growing conditions.

The seed is the plant's provision for a new generation. It contains the new plant and food for its early growth. Before a seed can grow, it must have the right conditions, warmth, moisture, and air. Before the embryo can use the food stored up for its use, it must digest it and distribute it. In getting free from the testa and in forcing its way through the soil, a new plant uses energy. Respiration releases the energy obtained from the food by oxidizing the carbon in the protoplasm of the young plant. The hypocotyl is the part of the dicotyledon embryo that helps it get out of the ground into the light. Although seeds will germinate without either soil or light, both are necessary for healthy growth and development of a land plant.

QUESTIONS

What is the function of a seed? What are the parts of a seed? What are the conditions necessary for germination? for growth? What is a seedling? What kinds of foodstuffs are stored in seeds? Why does a young plant

(embryo) need energy? What is the function of digestion to the embryo? of circulation? of respiration? What use does man make of the seeds of plants?

SPECIAL TOPICS FOR DISCUSSION

1. In what respects are you like a plant?
2. What characters or traits did you inherit from each parent? from your grandparents?
3. What factors of your environment are at least partially under your control?

REFERENCES

- Cook, *College Botany*, pages 108-128, J. B. Lippincott Company
Holman and Robbins, *A Textbook of General Botany* (second edition), pages 283-308, John Wiley and Sons
Sinnott, *Botany, Principles and Problems*, page 198, McGraw-Hill Publishing Company
Smith (and others) (1924), *A Textbook of General Botany*, pages 313-327, The Macmillan Company
Transeau, *General Botany*, pages 252-271, World Book Company

CHAPTER XXII

FORESTS AND FORESTRY

The groves were God's first temples.

—BRYANT

226. Tree Associations. — Trees that grow without the aid of man collect in large tracts known as forests. In a given plot, certain kinds of trees are more numerous than all the others, and give their name to the area although there are several other kinds of trees in the plot. We thus have associations of trees and also of smaller plants, because when plants grow in any locality in large numbers, they have been able to adapt themselves well to their surroundings or habitat.

227. The Making of a Forest. — When the first settlers came to America, they found forests that covered most of the land. Trees were so numerous that there was no need to be careful about cutting them. This attitude towards forests was continued by later inhabitants, with no thought of future generations. So, today, we find ourselves with few forests left, with few new ones growing, and with increasing needs for forest products. Thus it is that the subject is one of great importance. We are now trying to save from destruction the tracts that we have and are replanting areas that will yield forest products to later generations. It is estimated that a country should have at least one fifth of its area in forests to provide for its needs.

228. Federal and State Protection of Forests. — The forests of the United States now cover about 550,000,000 acres, or more than one fifth of the total area. According to good authority these resources are sufficient to supply our lumber industries and firewood consumption, provided the area is properly stocked and conserved. This can best be done by the federal and state govern-

ments, which appropriate huge sums every year for the protection of forests and the development of parks.

National Forest Preserves. — In 1891 President Harrison set aside the Yellowstone Park Timberland Reserve, which was the first forest preserve. Since that date other presidents have set



Courtesy Emanuel Fritz, University of California

FIGURE 283. A PINE FOREST

The tallest trees in this picture are sugar pine and yellow pine. Young white firs are recognizable by their horizontal branching.

aside other regions until there are at present one hundred and forty-nine national preserves with a total net area of over 156,000,000 acres.

229. Forestry. — In Europe, forestry has been practiced for a long time ; and methods of planting forests, caring for them, and cutting them are such that a continuous revenue is obtained from tracts devoted to forests. In the United States some progress has been made both by the states and by the federal government. Great diversity of conditions, however, has presented many

problems, not all of which are yet solved. Trees are now being considered as crops, and experiments are being made with a view to obtaining the greatest possible returns from a tract in the shortest possible time. In general, only the land not suited to the raising of cultivated crops is used for growing trees, although trees, like other plants, grow better on good soil than on poor. It has been found, too, that some kinds of trees, those used in



Courtesy Colorado Association

FIGURE 284. A SCENE IN ONE OF OUR NATIONAL PARKS

making paper pulp, for instance, can be used while they are still comparatively small. In some cases, quick-growing trees are alternated with slow-growing species, the former being removed to produce income and to leave room for the others to develop properly. In general, it has been found that the best way of obtaining young trees for planting is to raise them in nurseries from seed.

After a young forest is planted it must be guarded from its enemies, the foremost of which are fire, insects, and fungi. Forest rangers keep watch from look-out points or from airplanes for fires, and also patrol the forests. It has been found that the

larger number of fires come from man's carelessness with matches, cigarettes, and camp fires. Many are caused by lightning, also. When a fire is discovered, word is sent out and forces of men are sent to fight it. Paths free from trees, dead branches, and leaves afford means of access to different parts of the forest, as well as helping to confine the fire to a limited region.

Different methods are employed to combat insects, one being to scatter dust or spray from an airplane to destroy them. A



FIGURE 285. A PINE PLANTATION

U. S. Forest Service

knowledge of the life history of insects and their habits is needed by the ranger whose business it is to report and to help fight insects. Fungi are the hardest of all to combat, since they are spread by invisible spores, gain entrance where bark is broken, and often ruin a tree before their presence is apparent. Some of the worst fungal diseases are bracket fungus, white pine blister rust, and chestnut blight.

230. Lumbering. — The term *lumbering* includes, primarily, cutting the trees and getting them to the sawmill. Great waste has been characteristic of unscientific lumbering. This waste assumed two forms, injuring young trees in felling mature ones,

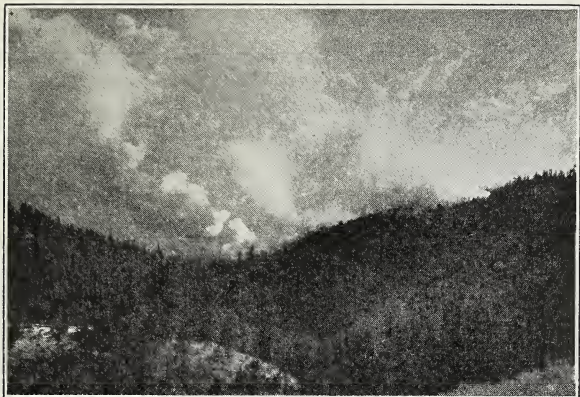
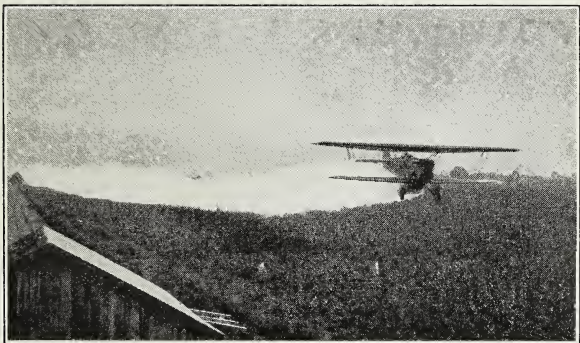


FIGURE 286. A FOREST FIRE

U. S. Forest Service

What kinds of damage do such fires cause? How can we help prevent these catastrophes?



Courtesy Delta Air Corporation

FIGURE 287. DUSTING A YOUNG FOREST BY MEANS OF AN AIRPLANE

How does this airplane help control insects?

and making use only of the most valuable part of the trees felled. The latter practice not only wastes much wood that might be

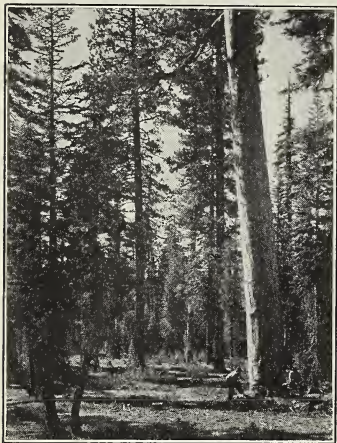


FIGURE 288. FELLING A WHITE PINE

What may happen to the smaller trees ?

used in many ways, but is also a menace to neighboring forests, for it leaves dead, dry tops and limbs lying about to supply fuel for a devastating fire.

When lumbering is done scientifically, injured young trees are pruned and treated so that they may not become diseased by the entrance of spores of wood-destroying fungi, and either all parts of the trees felled are made use of, or the less valuable are piled and burned under conditions that do not menace the safety of the remaining trees and that leave a clean

floor, one of the best possible protections against forest fires.

N.B. **231. The Importance of Forests.** — One has only to look about him at the great number of uses to which wood and lumber are put and the unsatisfactory results when substitutes for wood are used to realize that we are very dependent on forests for their products. Forests are useful also in preventing washing away of the soil, erosion, and in maintaining a steady flow of water throughout the year, a feature which is becoming increasingly important owing to the use of water systems in connection with large cities. It is said that the loss of soil by erosion now constitutes the foremost problem of agriculture. The loss of water and the destruction caused by floods and freshets are other important problems of forestry. When trees are growing close together, their roots intertwine and help to hold the soil in place. As the leaves and dead branches drop to the ground

and decay, a substance called humus is formed in a layer on top of the soil with which it finally becomes mixed. Humus has the property of soaking up water like a sponge, and giving it out again slowly. So, when snow melts in the spring, the closeness of the trees prevents its melting as rapidly as it does in the open, and the humus takes it up, preventing a quick run-off of water and ensuring a steady flow later. Areas that have long been

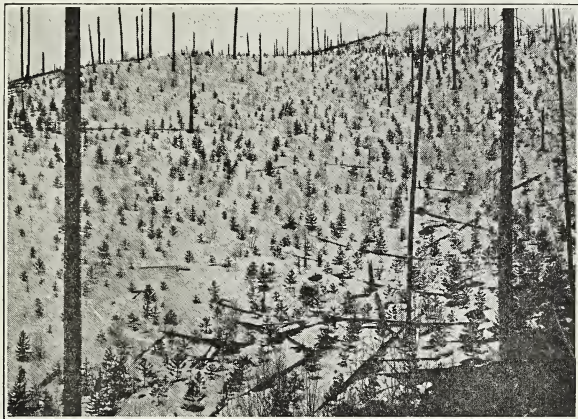


FIGURE 289. REFORESTATION

U. S. Forest Service

This burned-over area has been reforested to prevent erosion and to improve the soil.

deforested have lost their best soil through its being washed into gullies, which makes cultivation impossible. Another evil connected with the loss of soil is the clogging of channels used for navigation, entailing much expense in dredging to keep them open. Much attention is now being given to reforesting waste areas with the idea of improving the soil, preventing further erosion, and lessening the danger from freshets as well as maintaining a steady supply of water.

Two kinds of trees grow in forests: the narrow-leaved, evergreen, or soft-wood trees and the broad-leaved, deciduous, hard-

wood trees. These are lumberman's terms and not those of botanists, for the basswood in the second group has softer

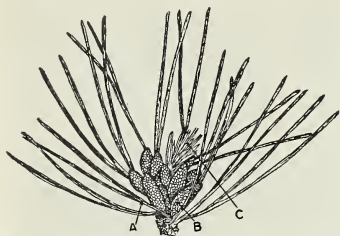


FIGURE 290. YOUNG POLLEN-BEARING ORGANS OF PINE

A, mature leaf; B, pollen-bearing organs; C, young leaves. How do they differ from the stamens of flowers?

wood than pine in the first group. The best primeval forests are now found in the southern part of the Appalachian region in the East, and in the Rocky Mountains and along the Pacific coast in the West. The oldest trees in the former forests are the pines. In the Western forests are found the largest and oldest living things, namely, the Sequoias.

232. Pine Tree as a Type. — The pine illustrates the plants of the evergreen group. The pine has all the parts of a flowering plant—stem (trunk), branches, roots, leaves, seed-producing organs, and fruit (cones).

Stem.—The trunk, the main stem, does not divide,—a marked characteristic of conifers (cone-bearing trees). In a forest where trees are crowded together and there is in consequence a struggle to get light, the trunks grow tall and most of the branches are near the top.

A cross section of a stem shows a series of rings, known

as annual rings, by which the approximate age of the tree can be told. In the spring, when all the conditions are at their best and



FIGURE 291. YOUNG OVULE-BEARING ORGAN OF PINE

A, young cone; B, young leaves; C, mature leaves. How does it differ from a flower?

growth is rapid, the cells of the tree are large and thin-walled, strength being sacrificed to size. In the fall or during a dry time in summer, the cells formed are much smaller and the walls thicker. These small cells which show most plainly limit the annual ring. During a season in which long, dry periods occur, more than one ring may be made. From the center to the bark extend medullary or wood rays. The part of the stem where increase in thickness takes place is just under the bark.

Branches.—The branches leave the stem almost horizontally and nearly in a circle around the trunk of the tree. In the pine they curve upward, but each kind of evergreen has its own habit of curvature in its branches.

Leaves.—The leaves, called needles, are long, slender, and curved on one side. They grow in bundles of two, three, four, or five needles, according to the kind of pine. The leaves, which are

borne but once in a place, remain on the tree from two to five years and then fall off, leaving the branches bare except near the ends.

Roots.—The roots of the pine vary according to the kind of pine and according to the soil, but they are always extensive.

Seed-producing Organs.—Early in the spring, two kinds of organs are found on the new shoots which grow from the terminal buds. The pollen bearers look like short catkins, and are borne in clusters near the base of the shoot. They consist of scales arranged spirally around



FIGURE 292. WHITE PINE CONE AND LEAVES

How many needles are there in a bundle?

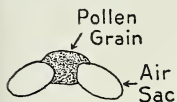


FIGURE 293. POLLEN GRAIN OF PINE

Of what use are the air sacs?

the central axis. Each scale bears two pollen sacs. They wither soon after shedding their pollen, although they may remain on the tree for a year. The other kind of organ, the ovule bearer, is short and thick, and is found at the tip of the shoot or on the side of the shoot near the tip. It, too, is made up of scales

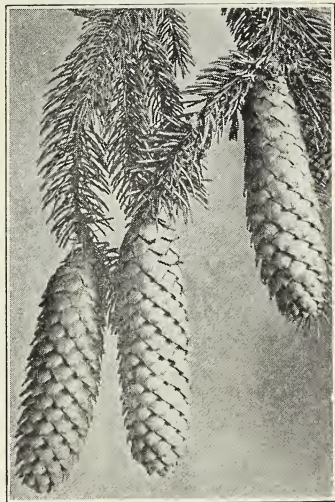


FIGURE 294. TWIGS AND CONES OF NORWAY SPRUCE

How does the arrangement of the leaves differ from that in the hemlock?

and allow the seeds to drop out. Each seed of our northern pine is provided with a wing by which it is blown about, for this pine depends on the wind to scatter its seeds as well as its pollen.

233. Related Forms of Conifers. — Hemlocks, spruces, and firs (balsams) have smaller, flatter needles than the pines and they are not arranged in bundles. Cedars have scale-like leaves.

arranged spirally around a central axis. Each scale near its base bears two ovules. When the pollen is ripe, each grain, being provided with wing-like air sacs, is easily blown about by the wind. Some of the pollen sifts into the ovule-bearing organ (young cone) through the spaces between the scales, which at this time are separated slightly. Then the scales close up; the cones turn downward and continue to grow for several months (Figures 291 and 292).

Fruit. — During the next year, the pollen grains which are shut up inside the scales put forth pollen tubes and fertilize the egg cells which develop in the ovules.

When the cones are about two years old, the scales open

Larch and cypress trees shed their leaves in the fall, but in other respects are much like the pines.

Habitat. — Most evergreens grow in sandy soil in temperate or in cold climates, but a few of them occur where it is very warm, and some where it is wet and swampy. The finest evergreen forests in the world are found in the western part of North America, on the slopes facing the Pacific Ocean.

Economic Importance. — The value of the conifers can scarcely be overestimated. Most of the trees are sawed into lumber for building purposes, but some of them are used in their natural form for telegraph poles, masts of ships, and timbers of mines. Wood pulp, from which most of our paper is made, is produced from small spruce trees. The by-products of this group of trees are of great value. From the pine come tar, pitch, turpentine, and resin, and the bark of the hemlock was formerly extensively used in tanning leather.



FIGURE 295. HEMLOCK TWIGS AND CONES
What characteristics help you to distinguish them from other evergreens?

FIELD WORK

Most of the work in connection with conifers should be done out of doors. Each of you should learn to know by sight all the local native evergreens and those commonly planted for ornament. You should note the method of branching and the character of the trunk compared with other trees. You should observe the position of the cones on the branches and be able to give the reasons therefor. In the spring look for the male and female organs, and for leaf buds in the winter. Examine the leaf scars and the external rings which mark a year's growth, and decide how many years each tree keeps its

leaves. Note the arrangement of the leaves on the branches, the annual rings in the wood and their relation to the grain of the wood, the resin on wounds, the curvature of the branches, and other features readily observed.

Make a list of the trees you know by sight. What are the characteristics of each? What are they used for?

Make a list of all other trees known to grow in your locality.

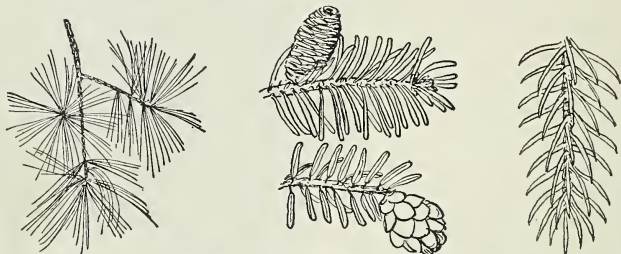


FIGURE 296. EVERGREEN TIPS (I)

Left, pine; upper center, fir; lower center, hemlock; right, spruce.

As a comparison will show, there are a number of differences between evergreens and trees that bear flowers. The chief one is that the seeds of the former are not covered or inclosed, but lie naked on the scale of the ripe cone. This peculiarity gives to



FIGURE 297. EVERGREEN TIPS (II)

From left to right, (first two) juniper or red cedar, white cedar, larch. Has any other evergreen than red cedar two forms of leaves?

the group one of its names, the *Gymnosperms* (naked-seeded). Another is that the leaves last for two or three years in most cases, instead of being shed every autumn, thus accounting for the term evergreen, so often applied to them. A third is that

evergreens usually contain a resinous juice that is lacking in seed-bearing trees.

Besides their association in forests, trees are grown singly and given a chance to develop symmetrically. In this case branches often grow almost to the ground instead of being confined to the top in their struggle for light as when closely planted. While the latter make the finest lumber, being free from knots, the former are more beautiful in shape.

Another use of trees is for shade as when they are planted along city streets. Maples, elms, sycamores, oaks, lindens, tulip trees, and ash trees are most satisfactory for this purpose. Some trees have peculiarities that make them unsuited for use as shade trees, for example, poplars that clog drains and water pipes with their roots, and that produce sprouts from their roots for a long time after they are cut. Elms, soft maples, and willows also clog pipes. Horsechestnuts and catalpas shed a great deal of litter, thus detracting from their usefulness as shade trees, though they are very beautiful when in full bloom.

234. The Care of Trees. — Shade trees often need help in securing enough water and food, and pruning to improve their shape. Also measures must be taken to protect them from insects of certain kinds. In pruning, limbs should be sawed off smoothly, close to the main stem, and freshly exposed surfaces should be covered with paint. The former precaution is necessary to insure quick growth of new wood over the injured part, and the latter is necessary to prevent the entrance of the spores



FIGURE 298. A MAPLE TREE

This tree is growing in the open and developing symmetrically. What other shapes do maples assume?

of fungi. Certain kinds of larvæ can be kept from getting to the foliage by painting the trunk with a sticky substance that catches and holds them or by tying bands of sticky paper around the trunk below the lowest branches. The presence of birds should be encouraged, especially the permanent residents that feed upon eggs and larvæ in the winter.



FIGURE 299. A CATALPA

This tree is prized for the beauty of its flowers as well as for shade.

235. Properties of Wood.

— The questions may arise, What makes wood so valuable? Is there nothing else that can be used in its place? One of its most valuable properties is that it is so easily shaped with sharp tools. Another is that it is light, compared with iron and steel, at the same time being tough and elastic. It has remarkable resistance to crushing, twisting, and pulling apart. A piece of yellow pine one inch wide and thick and a foot long, supported at the ends, bears a load of 720 pounds

without breaking. It requires a weight of 17,300 pounds to pull it apart, and a load of 7400 pounds to crush it. Many kinds of wood are pliable, a property which is often of much value, as in making tennis rackets. Wood is beautiful and it takes a high finish. Its beauty depends much on the grain, the closeness of which and the hardness of the wood determining its suitability for particular purposes. For instance, where woodcuts are to be made, the grain must be very small, and the wood very hard. Holly and box are best for this. In the case of wood used for pitchfork and shovel handles, the qualities desired are toughness and smoothness. These are found in ash and hickory, and so the list might be lengthened indefinitely. Balsa wood, newly



U. S. Forest Service

FIGURE 300. PRUNING AND THINNING A YOUNG PINE FOREST

This is work undertaken by the Federal government.

discovered in the tropics, is much lighter than even cork. This property gives it value in the life preservers and rafts used in case of accidents at sea.

236. Preservation of Wood. —

There are great differences in woods as to their ability to last in the soil or under water. Some, like cypress, cedar, and locust, have the ability to withstand decay on account of substances contained in the wood, such as resins. All wood lasts longer if it is seasoned, that is, allowed to dry out in the air before being used. Wood that is to be used in damp places, however, usually needs treatment to prevent or at least

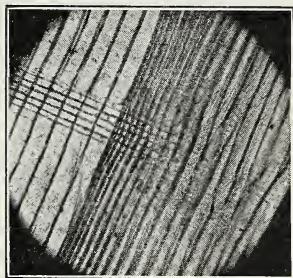


FIGURE 301. RADIAL SECTION OF A PINE TREE

The horizontal lines are medullary rays. Notice the narrow cells marking the end of a season's growth.

to retard the process of decay. As decay is caused largely by the work of bacteria or of fungi, both of which depend upon moisture as one of their chief requirements, the thorough drying of timber is one precaution taken to insure its lasting. Another method used

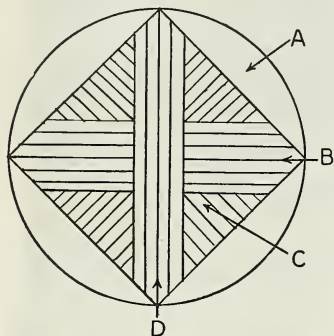


FIGURE 302. DIAGRAM SHOWING HOW LOGS ARE QUARTER-SAWN

A, slabs removed to square the log; B, C, short radial sections; D, long radial sections.

Note that at least one end of every section is oblique and that some of the sections are very small, entailing waste. Quarter-sawn lumber is used for furniture and for floors. What kinds of wood are most commonly quarter-sawn?

is charring portions that are to be covered by earth, and a third, the most common, is the use of chemicals. Railroad ties, for instance, are thoroughly impregnated with a solution containing creosote, among other substances, by being soaked in it for a long time or by having it driven in under pressure. This acts as an antiseptic, preventing bacteria and fungi from growing in the wood, and prolonging the usefulness of the timber to a remarkable degree. Although treating ties in this way is costly at first, it is an economic measure on the whole, for it saves the timber and the labor that would be used if the ties had to be replaced frequently.

237. Products Made from Trees. — Perhaps the most extensive use of the forests is for lumber. White pine was formerly the kind of pine most in demand as well as the most abundant. Now yellow pine is taking its place on account of the scarcity and high cost of white pine, although yellow pine is slightly inferior. White oak is highly valued for floors and furniture. Maple is a fine-grained, hard wood much prized for ballroom floors, furniture, and other purposes. Curly and bird's-eye maple are valued as wood for veneer (see next page), especially in bedroom furniture. The former has a wavy grain, and the latter numerous

glistening points scattered through it, thought to be undeveloped adventitious buds. Black walnut, cherry, and mahogany are very valuable for furniture. Hickory, elm, and ash are used for handles of tools and for parts of vehicles where toughness is required. Apple wood, holly, and box are sought for turned articles. Cedar, larch, and cypress are used for posts and poles, and basswood for trunks and crates on account of toughness, lightness, and elasticity.

Some trees, besides fruit trees, furnish valuable products other than wood. In some localities, maple trees are raised for the sugar and sirup which they produce. Chestnut, hickory, walnut, and other trees give us nuts year after year, as well as lumber when they are cut down. Willow trees give us a superior kind of charcoal used in medicine and in making certain kinds of gunpowder; the poplars and basswood or linden give us excelsior, so useful in packing fragile articles and in making cheap upholstery. Turpentine, obtained from the pine trees, is used in paint and varnish. Resin, another product of pine, has many uses. Veneer is a superior finish obtained by laying thin sheets of the more beautiful kinds of wood over the cheaper or less beautiful kinds. Wood alcohol, so useful as fuel, is obtained from wood wastes such as sawdust and shavings.

One of the most valuable products of the forests is rubber, which is made from the sap of the rubber tree. The value of this product and the extent of its use are enormous. Rubbers,



FIGURE 303. TAPPING A RUBBER TREE

The cut must be made into the inner bark where are found the cells containing the fluid from which rubber is made.

rainy-weather apparel, heels, erasers, bands, automobile tires, and wire insulation are only a few of its many uses.

SUMMARY

Write a summary of the chapter. Make it comprehensive, but concise.

QUESTIONS

What is a forest? How are forests useful to man? Why is reforestation necessary? What is being done to conserve forests? What are the duties of a forester? What is forestry?

How are evergreens like other plants? How do they differ from other plants? What kind of trunk is characteristic of soft woods? How does a tree which grows in a forest differ from one which grows in an open field? Why? What are annual rings? How are they formed? Describe the branches of the pine; the leaves; the roots; the organs which produce pollen and ovules; the fruit. Name the evergreens. Name various wooden articles that are in everyday use. Make a list of the uses to which lumber is put. What other products come from the evergreen forests? In what ways are forests beneficial? What are the governments doing to protect them? What regions in your own state are covered with forests?

SPECIAL TOPICS FOR DISCUSSION

1. Find the names and locations of the larger forest preserves in the United States and in your own state.
2. Make a note of the number and location of the abandoned farms in your locality that could be reforested. Find out how much it would cost.
3. Learn what you can about Albany's municipal wood-lot in New York.
4. From catalogues and circulars find out the requirements for becoming a forester; a forest ranger; a "tree surgeon."
5. How is the airplane being used in taking care of trees?
6. What is the work of the Civilian Conservation Corps?

REFERENCES

- Bergen and Caldwell, *Practical Botany*, pages 390-411, Ginn and Company
 Coulter, *Plant Life and Plant Uses*, pages 195 and 196, D. Appleton and Company
 Government pamphlets and bulletins
 Hough, *American Woods* (Published by the author, Lowville, N. Y.)
 Keeler, *Handbook of Trees*, Houghton Mifflin Company
 Moon, *The Book of Forestry*, D. Appleton and Company
 Sargent, *Trees of North America*, Houghton Mifflin Company
 Schenck, *Forest Policy*
 Snyder, *General Science*, pages 263-269, Allyn and Bacon

omit
CHAPTER XXIII

FERNS AND FERN-LIKE PLANTS

*Every fern is tucked and set 'neath coverlet
Downy and soft and warm.*

— SUSAN COOLIDGE

238. History of the Fern. — We have noted that forests, composed of the largest plants, have other plants growing among them, especially on the ground. Ferns are well-known plants of the woods. Others are the club-mosses, the so-called Christmas greens, and still others are the horsetails and scouring rushes, though these are found in the open as well as in the woods. Selaginella, a pretty greenhouse plant, also belongs to this group. All are interesting on account of their beauty and their history, as well as for their method of reproduction.

This whole group of plants is very old. At one time they grew as large as trees and they were very numerous. In their history they resemble reptiles, and like them, they are a declining race. They were at their height when the earth was younger and the climate was very wet and very hot. The largest of their survivors are still found in the tropics. In the temperate zones most of them grow best in moist, cool woods in a rich soil, though some have been able to adapt themselves to less favorable conditions. A study of coal beds shows that when the earth was covered with



FIGURE 304. A DRAWING OF A TREE FERN

Many, many years ago, these huge ferns were very numerous.

these giant plants, the dead ones accumulated in masses. These turned into coal under the influence of heat and pressure. Coal, oil, and natural gas appear to have been formed at the same time. None of these fuels is being formed at the present time, so far as



FIGURE 305. IMPRINT OF A FERN FROND
PRESERVED IN STONE

This fern grew three hundred million years ago.

we know, and it will be necessary for us to find a new kind of fuel when we have exhausted the present supply.

Ferns, like trees and smaller flowering plants, have roots, stems, and leaves. Unlike flowering plants, however, they do not produce seeds, but spores, and they reproduce by the alternation of generations as will be explained later. A study of

Pteris, a common and well-known fern, also known as bracken and brake, will illustrate the structure, the habits, and the reproduction of ferns in general.

239. *Pteris*. — This fern has a slender, underground stem or rhizome that is often several feet long which lives from year to year, putting up new leaves annually. Fine roots grow from the stem. The leaves, also called fronds, are pinnately compound, and have the structure of a typical green leaf except that the veins are forked, this kind of venation being characteristic of ferns. When the leaves appear above the ground in the spring, they are tightly rolled and covered with a hairy growth at the base. As they unroll they lose this covering. At certain seasons of the year lines form along the margin of the under sides of the leaves. These are made up of minute reproductive bodies, *sporangia*, each of which contains several spores capable of starting a new generation. There is great variety in the forms of the leaves of ferns and in the arrangement of the sporangia. Many ferns have the sporangia in round dots, each called a *sorus* and covered by a thin cover called the *indusium*.

The stem is less complex than that of a flowering plant. It is made up of well-defined clusters of cells, tissues, which have a constant relation to each other, a fairly constant position for each kind of fern, and the same functions as similar tissues in the flowering plants. The outside of the stem is covered by a thin

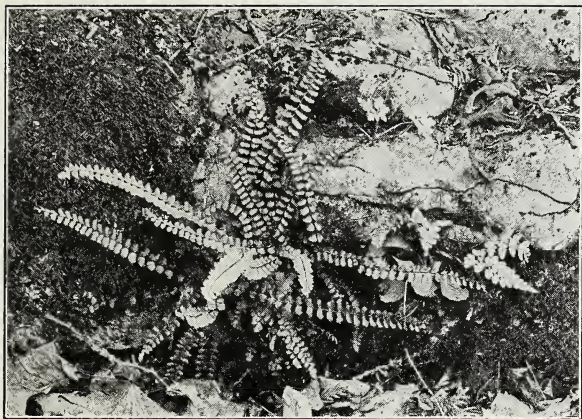


FIGURE 306. A MAIDENHAIR SPLEENWORT

This fern grows in New York State in limestone regions.

epidermis. Just inside the epidermis is a band of mechanical tissue of thick-walled cells to give support, and near the center of the stem two elongated masses, slightly crescent-shaped, besides numerous smaller masses distributed somewhat evenly throughout the stem. The conductive tissue in pteris is in definite groups, some large and some small, each made up of xylem and phloëm as in flowering plants. All the space not occupied by other tissues is filled with fundamental tissue in which most of the vital processes of the stem are carried on.

240. Life History of Pteris. — A sporangium, containing spores, is a lens-shaped body on a stalk with a row of thin cells above the stalk and a band of elastic cells from the stalk almost to the thin

cells on the front. When the spores are mature, the elastic cells exert a pull that causes the thin cells to split, opening the sporangium and forcibly discharging the spores. Those that fall in favorable positions sprout, forming a thread-like chain of cells. This develops into a heart-shaped body, the *prothallium*, which

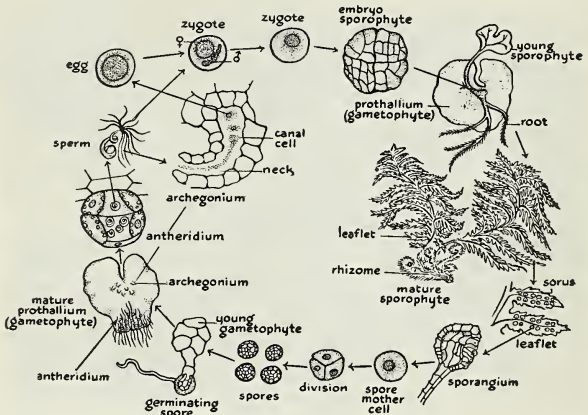


FIGURE 307. LIFE HISTORY OF THE FERN

has a notch on the upper side and filaments, or *rhizoids*, on the under side by which it gathers moisture and attaches itself lightly to the soil. Among the rhizoids, near the lower margin, a group of *antheridia* develop, each one short, spherical, and containing a number of motile sperms. Near the notch, on the under side, a few *archegonia* (female organs) develop, each one containing an egg cell. Each archegonium resembles a curved, inverted vase, filled with mucus and closed at the end by a cap or layer of cells. When all parts are thoroughly wet, the mucus swells, pushes off the cells at the end, and permits the entrance of a motile sperm that has been attracted to it. The sperm then makes its way through the mucus to the egg and fertilizes it. From the *zygote* that results a new fern plant begins to grow, pushing its

root through the bottom of the archegonium and deriving its nourishment parasitically from the prothallium while it is putting up leaves that can make its own food. When the young fern plant is able to carry on its life independently, the prothallium dies. Because the prothallium produces eggs and sperms it is the sexual generation of the fern. The large, green, showy plant which grows from it and produces spores is the *sporophyte*. Thus the sporophyte generation gives rise to the gametophyte, or sexual generation, and that, in turn, to a new sporophyte. The gametophyte is so small as to escape observation, and it dies when its work is done, while a sporophyte once established, is perennial. Eggs and sperms do not usually mature at the same time on the same prothallium, thus preventing self-fertilization. The sperm, being motile, is dependent on moisture to enable it to swim from one prothallium to another. Rain and dew make it possible for the sperms to reach prothallia on which ripe archegonia have opened.

241. Fern Allies. — Club moss is one of the smaller forms of plants that resemble ferns in their habits and life history. These grow in the woods, some as single plants and others as trailing plants familiar to us as "Christmas greens." Their spores are borne on specialized branches in sporangia on scales which represent modified leaves. They have an irregular prothallium.

Horsetail, or equisetum, grows in waste places either wet or dry. It is peculiar in having two types of plants each season, the first appearing early, growing rapidly from food stored up the previous



FIGURE 308. HART'S TONGUE FERN

This is a rare fern that grows with an undivided leaf.

season, lacking the ability to make food for itself, and having the sole function of producing spores. These grow in sporangia at the top of the stalk, — the cluster being called a *strobilus*. The perennial stem is underground. The fertile stalk is made up of nodes and internodes, each node having a collar of reduced leaves around it. The stalk is hollow, and the outside is more or less ribbed. After the fertile stalk has shed its spores, it dies and is replaced by a sterile stalk which is green and bushy from repeated branching, the stalk performing the work of photosynthesis and storing food in the underground stem for the growth of the fertile stalk of the next season. Scouring rush is a form of equisetum in which one stalk performs both functions. It has the peculiarity of being covered with a glassy substance, a characteristic that made it valuable for scouring floors, pots, and kettles before the days of modern scouring powder.

LABORATORY SUGGESTIONS

Make a collection of the ferns that grow in your locality and note the variety of branching of the leaves. Learn to name each. Make fern prints in your printing frame.

Sow spores on the top of water in a tumbler. Cover, set in the shade, and look for prothallia in about a week. Compare ferns with flowering plants in every way you can think of.

242. Mosses. — Moss plants are small, and they tend to grow crowded together in cushions. They consist of distinct stems and simple leaves, but lack true roots. In place of them they have rhizoids which serve as organs of attachment and absorption. In the leaf there is only the midrib which in many mosses does not extend to the tip of the leaf. The leaves are well supplied with chlorophyll, and the plants grow erect. If a cushion of moss is examined, it is found to consist of two kinds of plants, one having a saucer-shaped top, and the other a pointed top resembling a candle flame. The latter, at certain seasons of the year, is surmounted by a stiff wiry stalk bearing a capsule. This may be covered by a shaggy cap.

243. Life History. — If a dry capsule is shaken, it sheds light, powdery spores like the “smoke” of a puffball. When these spores fall on moist places, each puts out a mass of fine threads called *protonema*. These threads produce buds from which the leafy moss plants grow. On some of these, sperms are formed in antheridia, on others eggs are formed in archegonia, and on still others both antheridia and archegonia are produced. When the sperms are ripe, they are expelled from the antheridia forcibly. If water is present they swim about till they come in contact with an archegonium containing a ripe egg which they fertilize, thus starting a new individual.



FIGURE 309. MOSS PLANTS SHOWING SPORO-PHYTES AND GAMETOPHYTES

The green moss plant is thus the gametophyte generation, as it produces eggs and sperms. The new plant that develops from the fertilized egg is the sporophyte generation. It cannot make its own food, so it lives parasitically on the female gametophyte on which it grew, getting its nourishment from it through a pad called a foot which pushes down through the bottom of the archegonium where it begins to grow. It has for its work only the production of spores, asexual bodies from which the sexual plants grow. The alternation of generations in mosses differs from that in ferns in this respect: in the latter the sporophyte is the conspicuous generation, while in mosses, the gametophyte is more conspicuous and independent.

244. Habitat. — Mosses live in a variety of habitats, but thrive best in damp, shady woods on decaying logs and on stones wet by spray. All are dependent on water for reproduction by eggs and sperms, though some are able to exist for long periods without

water by drying up and carrying on the life processes at a very slow rate. They revive quickly, however, when moisture comes, and resume full activity.

SUGGESTIONS FOR THE STUDY OF MOSSES

If you live in a city, you will find mosses growing in crevices of walls and copings, on trees, in cracks of sidewalks, on the brickwork near the base of houses, on old paths, and in other places where you might not expect to find them. Keep watch of a particular cushion of moss, watching the change in appearance when dry, when moist, and when it has sporophytes. Examine the specimens you find and try to determine how many kinds of moss grow in a limited locality, such as in your dooryard or on the trees along your street.

245. Plants Related to Mosses. — *Marchantia* represents a number of plants in the same group as the mosses. It is a ribbon-like, flat plant that grows along the surface on which it lives attached by rhizoids. It lacks roots, stem, and leaves but it has a midrib which branches, and more or less curly edges, and on the surface tiny cups containing vegetative bodies called *gemmae*. At certain seasons it puts up two kinds of branches, one of which bears antheridia and the other archegonia. The former is like a saucer, with the openings of the antheridia scattered over its surface. It holds water of which the motile sperms make use in swimming to an archegonium. The latter is like the ribs of an umbrella. Archegonia grow on the lower side of each. When a ripe egg is fertilized, it grows into a bell-shaped sporophyte. This hangs down from the under side of the archegonial branch, sheds its spores by means of elaters, thread-like bodies which twist about as they absorb water and lose it again; and the spores start a new green, gametophyte generation.

246. Algæ. — We have seen that mosses are plants that are adapted to live on land and that they have the beginnings of systems for carrying on the vital processes, and that they reproduce by the alternation of generations. There is another group of plants, most of which cannot live out of the water, that have no tissues, and that reproduce in various ways. These are the Algæ. Being supported by the water in which they live, they

have no need of a mechanical system to hold them up. Besides, they are less likely to be torn or bruised if they can move with the water. All of them have chlorophyll, but in some this is hidden by pigments of other kinds. The possession of chlorophyll enables them to make their own food. They digest it as other plants do, and use the digested food locally, thus doing away with the need of a circulatory system. Oxygen is obtained



FIGURE 310. MARCHANTIA, A LIVERWORT

This is a plant that grows in moist places. At certain seasons it has fruiting stalks that rise from the ribbon-like "leaves."

by each cell from the air in the water in which they grow, and the wastes are cast off by each cell into the water. Many of the algæ are filamentous (thread-like), some grow in colonies of other forms, and still others are unicellular. It is a motley group. Because they have no division into root, stem, and leaves, they are known as Thallophytes.

247. Classification of Algæ. — The popular classification of algæ is by their color, namely, the blue-green, the green, the brown, and the red. By brief descriptions and illustrations you will be able to get a general idea of the group.

The Blue-Green. — These are found in water or on very damp earth where there is much decaying organic matter. They are the simplest, lacking a definite nucleus. Some of them color the water in which they grow, and give it a fishy taste. They reproduce only by fission or by the breaking apart of filaments each of which then grows to full size. Many of them secrete a jelly-like covering.

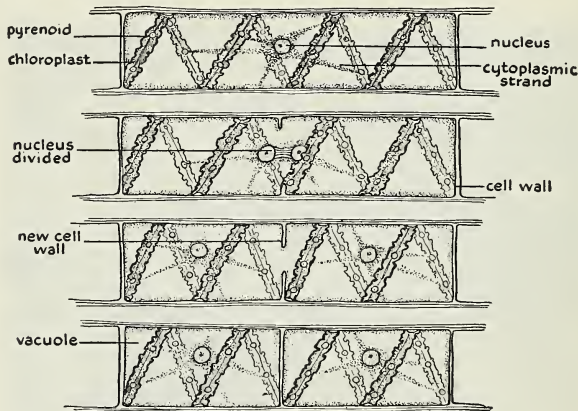


FIGURE 311. CELL OF SPIROGYRA

This diagram shows plant dividing. Note that the nucleus divides first.

The Green Algae. — This group contains many forms; unicellular, filamentous, colonies, and large sheets. Pleurococcus belongs to the first form, spirogyra to the second, pediastrum to the third, and, in salt water, ulva or sea lettuce to the last. Some of the filamentous grow attached to stones and other objects in the water. Others float, being made light by the bubbles of gas produced by photosynthesis and respiration. In spirogyra, also known as "frog's-bit" or pond scum, the chlorophyll is arranged in a spiral band, single or double. This plant divides by fission most of the year, but in the fall it puts out projections from cells that lie opposite each other, forming a canal through which the

contents of one cell pass into the other and unite with it in the form of an oval mass, called a *zygote*, with a hard cover to protect it in winter. In the spring a new filament is started from this body.

The Brown Algæ. — This group contains the largest forms. They grow in the salt water, either attached to rocks, as in the case of fucus or rockweed, or floating, as in the case of sargassum, which sometimes covers hundreds of square miles of water as in the Sargasso Sea. These algæ have divisions that resemble stems and leaves, and in the large, attached forms,

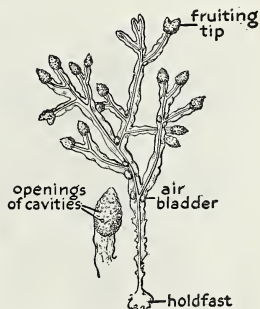


FIGURE 312. FUCUS, A BROWN ALGÆ

a holdfast that resembles a

At the left is shown an enlargement of a fruiting tip.

root. The group has a leathery texture to resist being torn by the motion of the water. Some specimens growing in deep water attain a length of from twenty to seventy-five feet. Fucus is of especial interest because of the eggs and sperms produced in cavities and set free in the water. There the eggs are fertilized and a new plant started.

The Red Algæ. — These are mainly marine, brightly colored, and delicate in form. Most of them are small. Our chief interest is in the fact that some are the source of food, and that some have a very peculiar structure, each cell being made up of a number of tubes in a vertical position which



FIGURE 313. CAVITIES OF FRUITING TIPS

These are detailed drawings of the cavities shown in Figure 312.

connect with those in the adjoining cells. In this group, too, are found the beginnings of the alternation of generations.

Diatoms. — A distinct group of unicellular algæ is often discussed with the brown algæ on account of their color, though it is

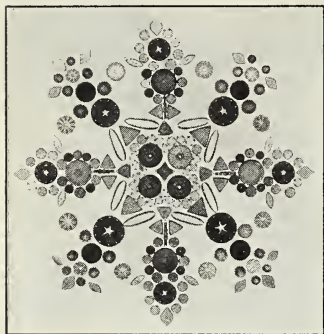


FIGURE 314. DIATOMS

More than a hundred of these minute plants have been arranged to form this design. These plants live in glass houses.

difficult to associate their structure with any other organisms. These are the diatoms, of varied shape, in two parts, like box and cover, and containing a glass-like substance called silica. Their method of reproduction is to separate the two parts and to build in a new "box" in the case of the cover, while the part that was the "box" in turn becomes a new cover, its new part being smaller than itself. Diatoms have the power of motion, but we do not know how they produce it. The remains of dead

diatoms are found in layers both in the sea and on land. They are used as the basis of scouring powders and in other ways.

SUMMARY

Ferns and their allies are simpler plants than those that reproduce by means of seeds. Their life history shows the alternation of generations. They were formerly much larger and more abundant than at present and they formed a considerable part of the vegetation that was the beginning of coal beds.

Mosses and their allies are much simpler in structure than are the flowering plants and the fern group. All are small, and very dependent on water, especially for securing fertilization of the egg.

QUESTIONS

What plants compose the fern group? the moss group? What is alternation of generations? Which is the conspicuous generation in ferns? in mosses? In what other ways do these plants reproduce?

SPECIAL TOPICS

Read about the "Carboniferous Age."

What uses are made of sphagnum moss?

REFERENCES

Cambell, *General Elementary Botany*, Chapter XIV, T. Y. Crowell Company
Mottier, *College Textbook of Botany*, Chapters XV and XVI, P. Blakiston's Son
and Company

CHAPTER XXIV

A GLANCE AT THE SIMPLEST ORGANISMS

Truth needs no colour.

— SHAKESPEARE

248. Introduction. — We have seen that the plants in the fern group are less complex than flowering plants, and that mosses

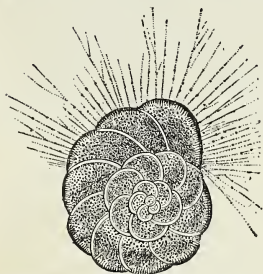


FIGURE 315. ONE OF THE FORAMINIFERA

All the Foraminifera are Protozoa. Numerous pores (foramens) in the test (shell) permit threads of protoplasm (pseudopodia) to extend outward. Some of these shells exceed three inches in diameter although they are Protozoa.

the mouth, which is surrounded by delicate, thread-like arms called *tentacles*. The body is composed of three layers, the outer layer, *ectoderm*; the middle layer, *mesoglaea*, non-cellular; and the inner layer, *endoderm*.

Each layer does some particular work for which the others are not fitted. For example, the outer layer contains cells which are especially sensitive to stimuli and many modified muscle cells

are still more simple. In completing our study of plants and animals we must give some attention to those not commonly seen on account of their small size. Hydra will serve to illustrate a group of animals that are many-celled, and that have two tissues but no complex organs. Bread mold will show us how it and similar plants live. Finally we shall study one-celled organisms, some living in colonies and some as distinct individuals. These represent the simplest expression of life.

249. Hydra. — The hydra is an interesting fresh-water animal about a quarter of an inch in length. Its body is shaped like a little cylindrical bag with only one opening,

that enable the animal to move about. The inner layer contains cells provided with flagella which catch the food particles for the inner cells to digest. The muscular action of the outer layer moves the entire animal. The sensitive cells enable the animal to recognize its prey. The food digested by the inner layer is used by all the cells of the body.

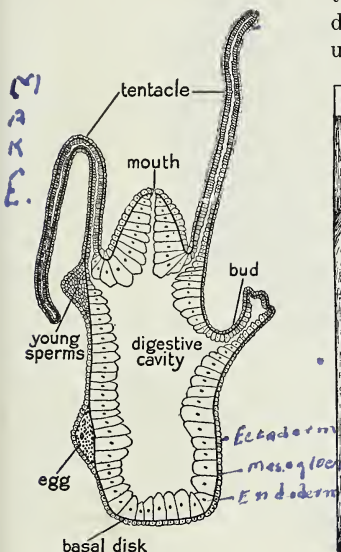


FIGURE 316. DIAGRAM OF HYDRA

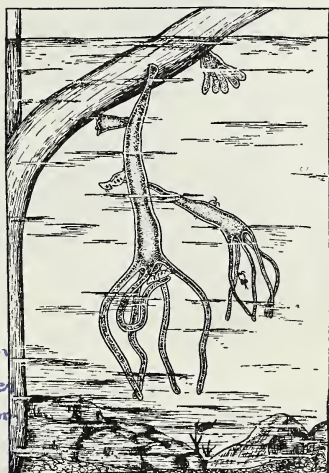


FIGURE 317. HYDRA SHOWN ATTACHED

Tentacles, usually six in number, are hollow, finger-like branches connected with the body cavity. They are provided with stinging cells which help the hydra to capture living water fleas and the like.

Locomotion. — The adult hydra is usually found attached as in Figure 317. In this condition the only movements possible are such as take place in the expansion and contraction of the whole body. The tentacles wave in the water, and as the hydra expands, the body may move first in one direction, then in another.

At infrequent intervals, however, the hydra detaches itself and moves from place to place by attaching the tentacles, then the base, then the tentacles, much like a boy turning handspings.

Nutrition. — The hydra feeds mostly on small animals, which



American Museum of Natural History

FIGURE 318. MODEL OF A JELLYFISH

The jellyfish, which is not really a fish, but a very simple animal, belongs to the same group as hydra and the corals. The jellyfish shows a number of important adaptations which are due to its free-swimming habit. Can you name any of them after looking at this picture?

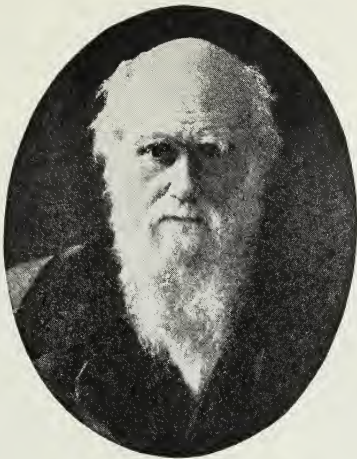
jars, a moving animal, or an enemy. It is able to contract, expand, and move the tentacles so as to bring food to the mouth, although it possesses neither nerves nor a brain. When a special study of the structure of the hydra is made, nerve cells are found which assist it in responding to stimuli and in correlating its movements.

Reproduction. — The hydra reproduces both sexually and asexually. In sexual reproduction eggs and sperms are produced by

are rendered inactive by the stinging cells, or darts, discharged from the tentacles of the hydra. The paralyzed animal is then brought to the mouth by the tentacles (Figure 316) and swallowed. Within the body, the nutritive parts are digested by enzymes as in other animals and absorbed. The indigestible skeleton of the animal eaten is cast out through the mouth.

Respiration and Excretion. — Oxygen is absorbed from the water by the cells of the ectoderm. The water that enters the mouth carries oxygen which is absorbed by the cells of the endoderm. At the same time the carbon dioxide from the cells is thrown off into the water.

Irritability. — The hydra is able to appreciate a variety of different kinds of stimuli such as



CHARLES DARWIN (1809–1882) made many original observations on animals and plants and conducted numerous experiments with them. But he was not satisfied simply to discover new facts; he wished to find some explanation for them. Just how all the many forms of life came to live where they do and to have the size and habits that they do is hard to determine. Darwin believed that there was a natural struggle continuously going on in nature between the weak and the strong, and that some which could run faster and eat more kinds of food were able to live in the competition, while the ones that lacked such ability died. He formulated a number of explanations. The best known of his theories is that of the origin of species by natural selection.

The main idea emphasized by Darwin in this theory is that life has gradually unfolded or evolved (hence evolution), passing from the simpler types like sponges and hydra to the more complex as the division of labor sets organs more and more apart.



the ectoderm cells. The sperm cells escape into the water and, like sperm cells of all other animals, have the power of locomotion. The fusion of the egg cell and a sperm cell starts growth, which results in the division of the egg cell into many other cells.



FIGURE 319. HUNTING TRUFFLES

In France, pigs or dogs are used to hunt truffles, an edible fungus which grows just beneath the surface of the ground. The insert shows a basket of truffles.

Hydras also reproduce asexually by budding. The buds soon separate from the parent and begin an independent life.

250. Fungi. — There is a great variety of fungi, from simple kinds to complex. It will help us to understand the structure of mushrooms and toadstools if we first study bread mold, a plant that has many cells loosely organized.

251. Bread Mold. — When examined with the naked eye, bread mold appears like a thick mass of felt, made up of colorless, closely interwoven threads. These threads, called *hyphæ*, are of two kinds, one lying on the surface of the bread or just below it, and the other standing upright above the surface. The first are the nutritive *hyphæ*, which absorb and digest food; and the

second are the reproductive. On the ends of the latter are round bodies which are full of black spores, each of which is capable of producing a new mold plant, if it falls into a place where conditions are favorable for growth — that is, where it has plenty of food, the right degree of warmth, and sufficient moisture. Other kinds of fungi may usually be found on a loaf of bread after three or four days, as spores of many kinds of molds are floating in the air at all times (Figure 320).

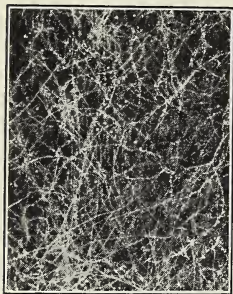


FIGURE 320. BREAD MOLD SHOWING MYCELIUM AND SPORANGIA IN EARLY STAGES

How does the color of the sporangia differ from that of the ripe ones in the following figure?

Some forms of fungi, like yeast and bread mold, are small and inconspicuous. Others, like puffballs and field mushrooms, are larger. Puffballs and mushrooms have their hyphæ compact and in layers resembling tissues. In the case of bracket fungi, such as grow on trees, the outer parts become hard and woody, causing them to resemble higher plants. A field mushroom consists of an expanded upper portion, the cap or pileus, on the under side of which are the gills, and a supporting stalk called the stipe. In other kinds, the stipe expands into a bulbous body at the base, or appears to grow out of a cup. The stipe may have a ring around it. By these and other marks one is able to distinguish the edible from the non-edible forms of fungi. Edible fungi are good food but some of the non-edible kinds are very dangerous. Fungi include many forms known as blights, smuts, and rusts, most of which are harmful to cultivated plants.

252. Unicellular Organisms. — All plants and animals that consist of a single cell have this in common, that each cell performs all the vital processes for itself. In the matter of food, however, several classes may be made. The fungi depend on food already made. If the food is living, the fungi are called parasites; if it is dead, they are known as saprophytes. The

animal forms eat living organisms, but do not parasitize them in most cases. Our interest in these forms is not only in the way

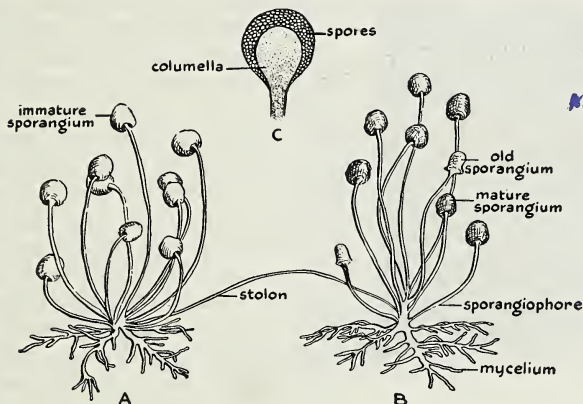


FIGURE 321. BREAD MOLD, HIGHLY MAGNIFIED

A, immature plant; B, mature plant; C, sporangium, magnified.

What flowering plants use stolons for propagation? (See page 252.)

they perform their vital processes, but also in their relations to other organisms. Yeast and pleurococcus will introduce us to unicellular plant forms, while the ameba will serve as a representative unicellular animal form.

253. Physiology of the Yeast Plant.

— This has some peculiarities not before mentioned. The favorite food of yeast is a certain form of sugar which it absorbs through its wall. This it digests by an enzyme, *zymase*, which breaks the sugar up into alcohol and carbonic acid gas, both of which are passed off as waste. When oxygen for respiration is not present, yeast

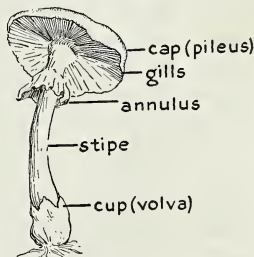


FIGURE 322. AMANITA, A POISONOUS FUNGUS

The orange cap of this fungus serves as a danger signal.

cells can make use of the energy obtained from the breaking up of sugar. Yeast reproduces by budding, often forming chains of cells, and rarely by the formation of spores. When proper vital conditions are lacking, it remains inactive and resumes normal living when conditions again become favorable. Yeast cannot live in more than a certain amount of its own wastes. The action of yeast on sugar is known as fermentation. It has long been used in the preparation of leavened (light) bread and in the making of beverages containing alcohol. For both processes only a definite kind of yeast is used in order to produce the effect desired. There are many kinds of wild yeasts, some of which interfere with the work of the



FIGURE 323. BRACKET FUNGUS ON AN OLD POST

cultivated yeasts used by man, so pure cultures (those containing only one kind) are kept on hand and wild yeasts kept out.

In the making of bread, yeast is mixed with moist flour, and a little sugar added to the dough. The yeast plants grow rapidly, setting free large quantities of gas. This is caught in balloon-like pockets of the sticky dough which it renders porous or light. Alcohol is present also. When the dough is baked, both the carbon dioxide and the alcohol are driven off, and the sticky protein in the flour is coagulated. When alcoholic liquors are manufactured, the gas is allowed to escape and the alcohol re-

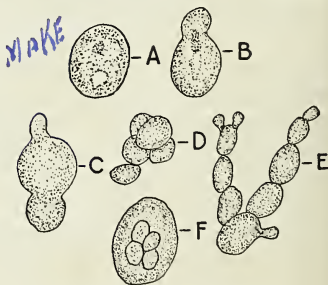


FIGURE 324. YEAST PLANTS

A, single cell; B, C, cells with buds; D, cluster of cells; E, chain of cells; F, cell with spores. How do they differ from *Pleurococcus* (Figure 326)?

tained. The skins of fruits usually have on them many kinds of wild yeasts that live on the ground and absorb their nourishment from it when it is damp. They are blown about when dry, and so alight on fruits. When the fruit skins are broken, as happens in crushing apples and grapes, the yeasts act upon the sugar in the fruit, turning the juice to cider, wine, etc.

254. *Pleurococcus*. — This is a green cell of microscopic size. It is very abundant, showing as a green coating on the bark of trees, on old boards, walls, and walks, — anywhere that moisture comes frequently and is retained for a time. A single plant has a thick wall of cellulose, and the other parts common to a cell. The chloroplasts are so dense, however, that it is not easy to see the various parts unless they are especially prepared for study. Like other green plants, *pleurococcus* manu-

factures its own food, and within the limits of its tiny size it digests, circulates, assimilates, respire, and excretes. Reproduction is only by fission. Sometimes the mother cell retains the daughter cells within its wall until they, too, have divided. The cells often cling together in masses. *Pleurococcus* is remarkable for its ability to carry on its vital processes at a very low rate when conditions are not favorable, and to resume them actively and quickly when they improve. When dormant the cells may be carried about by the wind. *Pleurococcus* differs from the ameba in not being able to move, in having a thick wall, in living in the air, and in making its own food. It is like the ameba in being an

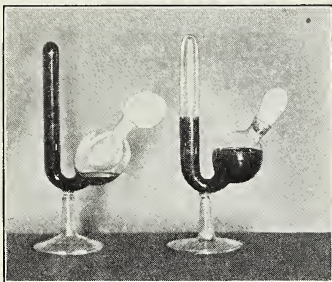


FIGURE 325. FERMENTATION TUBES

The bulb is filled with nutritive liquid containing yeast plants. As they grow they form carbon dioxide gas, which collects in the bulb, forcing the liquid into the upright arm. These tubes are used in estimating the number of yeast plants in a substance and the rapidity of their growth. In what industries would such information be useful?

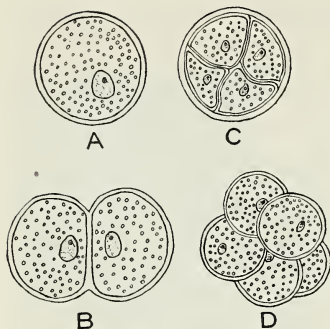


FIGURE 326. PLEUROCOCCLUS

A, single plant; B, plant dividing; C, four new plants within cell-wall of mother cell; D, group of plants.

How do these unicellular plants differ from cells you have studied in earlier parts of the book?

There is no well-defined cell wall; therefore the ameba is an illustration of a living, naked cell. Near the center of the cell

independent entity and in carrying on all the vital processes.

255. Ameba,¹ the Simplest Animal Known. — The ameba represents one of the simplest forms of animal life known to us. It can be studied only with the aid of a microscope.

It is difficult for inexperienced students to see the living ameba through the microscope, because the whole cell has a faint, grayish appearance, and in a strong light is transparent. But if this grayish appearance of protoplasm is once seen, it is always remembered.

¹ It is not always possible to secure amebæ. They are more frequently found in the slime and mud of stagnant water than anywhere else. paramecia and other infusoria can usually be secured in abundance by placing a handful of hay or leaves in a jar and covering them with the ordinary water used in the laboratory. This is called a *protozoan culture*, and should be started about four weeks before the material is wanted for class study. The length of time that the culture should stand can be lessened by adding a little beef extract and by keeping the jar near a radiator. Water sufficient to keep the hay or leaves covered must be added from time to time. When a good culture of paramecia is once secured, the jar should be kept from year to year; simply add water to the dried hay left in the jar when Protozoa are desired.



FIGURE 327. PHOTOMICROGRAPH OF AN AMEBA

is a spherical mass of denser protoplasm called the *nucleus*. In many amebæ the nucleus is not easily seen unless it is specially stained. The rest of the protoplasm in the cell is called *cytoplasm*. This does not appear the same in all parts of the ameba.

On the outside, there is a thin, almost transparent layer, called *ectoplasm*. The larger part of the cytoplasm is filled with numerous small granules and contains several vacuoles or tiny cavities. This inner mass of cytoplasm is called *endoplasm*. The vacuoles in the endoplasm may contain food, water, or waste products. The food and water vacuoles are temporary structures, but the vacuole which collects the liquid waste is always present.

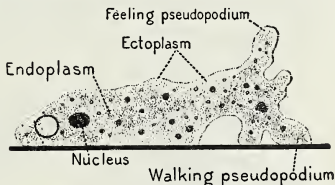


FIGURE 328. DIAGRAM OF AN AMEBA

The living ameba is continually changing shape and pushing out from the surface of its body blunt, finger-like projections of the protoplasm called *pseudopodia*, which give an irregular outline to the body (Figure 327). Sometimes the pseudopodia branch out.

256. Vital Functions of the Ameba. — The ameba has the same life functions as the higher animals, but of course you must think of the process rather than the structure, for you must imagine a single cell as taking food, digesting, assimilating, excreting, respiring, and reproducing.

Motion. — When the ameba sends out a pseudopodium in any direction, the rest of the body flows gradually, by a rolling movement, in the same direction. This creeping-rolling motion of the protoplasm enables the ameba to move through the water.

Nutrition. — When the pseudopodium comes in contact with a minute plant upon which the ameba feeds, the protoplasm of the pseudopodium surrounds the plant and takes it into the cell. The microscopic plant thus eaten by the ameba is inclosed, with a small amount of water, in a tiny globe called the *food vacuole*. The food vacuole is to be thought of as a stomach in which diges-

tion can take place, for the plant is digested in it. Digestion is accomplished by means of an enzyme. The nutritious parts are absorbed into the protoplasm, the undigested parts are cast from the cell, and the food vacuole disappears.

Food vacuoles are not always round (Figures 329 and 330), but take their shape from the form of the plant eaten.

Respiration. — From the oxygen dissolved in the water, the ameba obtains by osmosis the oxygen necessary to its life, and it gives off carbon dioxide from the cell.

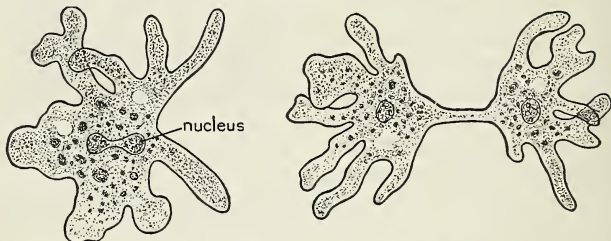


FIGURE 329. AMEBA REPRODUCING BY FISSION

Excretion. — The term *contractile vacuole* is given to a vacuole which is always in the protoplasm of the ameba.

This vacuole can be seen to increase slowly in size, then suddenly contract. As it contracts, the fluid in it is forced to the outside of the body of the ameba. The filling out of this vacuole is due to the collection of excretory wastes from the surrounding protoplasm. It is called a contractile vacuole because it contracts and expands, and an excretory vacuole because it collects and expels waste products.¹

Reproduction and Encystment. — The chief method of reproduction in the ameba is simple. The living cell divides into two equal parts, forming two new cells. This process is known as *fission*.

¹ The recent students of the nature of the contractile vacuole claim that it does not have an excretory function but is an organ of circulation. Until we have further study of this feature of Protozoa, it is permissible to retain the present explanation.

When the food or water becomes unsuited to supply the needs of the cell, the ameba in order to live often secretes (makes for itself) a thick wall completely surrounding the protoplasm. This process is termed *encystment*. After the wall has been formed, the ameba is able, for a long period, to resist cold, the drying up of the pond, or the lack of food.

257. Paramecium. — One of the most common forms of Protozoa is the slipper-shaped *paramecium*, which is more active than the ameba. It is abundant in stagnant water and in the hay infusions prepared in the laboratory.

Structure of Paramecium. — The paramecium, like the ameba, is a single cell, but it has both a large nucleus and a small one. It has an endoplasm, an ectoplasm, and a *cuticle*, or cell wall. Through the cuticle there extend great numbers of *cilia*, or threads of living cytoplasm. The ectoplasm contains many thread-like darts known as *trichocysts*. These may be discharged. Within the cells are found food and water vacuoles as in the ameba; but there are two contractile vacuoles, one at either end, and the food and water vacuoles are more numerous than in the ameba.

258. Life Processes of Paramecium. — The structures used in carrying on the life processes of the paramecium are not quite so simple as those of the ameba, but are much simpler than those of higher animals.

Locomotion and Defense. — The animal moves by means of the cilia, the direction depending upon the angle at which the cilia are held. You can see that the animals move backward and forward, and that they also rotate on the long axis. Paramecia defend themselves by discharging their *trichocysts*. This dis-

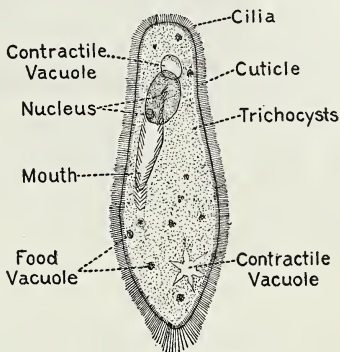


FIGURE 330. DIAGRAM OF A PARAMECIUM

charge occurs either as a result of certain strong artificial stimuli, such as electric currents or chemicals, or naturally because of collision with certain other Protozoa. If attacked by some animal which feeds upon them, they discharge the trichocysts in the region of the attack (Figure 331).

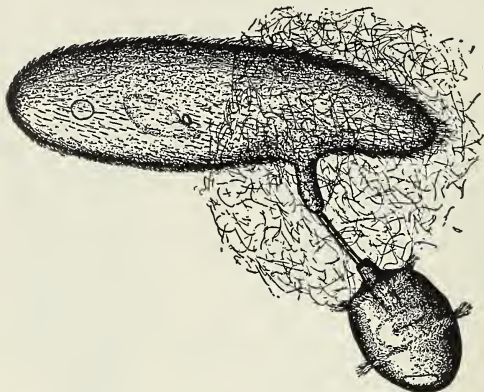


FIGURE 331. PARAMECIUM REPELLING AN ENEMY WITH ITS TRICHOCYSTS

Nutrition. — The food of the paramecium consists mostly of bacteria, which are collected by means of the cilia located on each side of the fold or depression called the gullet. At the inner end of the gullet is the mouth (Figure 330). The food thus collected passes into the protoplasm in the form of food vacuoles. Digestion is accomplished by the aid of enzymes which put into solution the available parts of the food; the indigestible parts are cast off from the body of the paramecium.

Respiration. — As in the ameba, oxygen is obtained from the air always found in water and it passes into the protoplasm at all points.

Excretion. — Excretory wastes are first collected in the two contractile vacuoles and then cast from the body. Gases escape from the entire surface.

Irritability. — Both the ameba and the paramecium respond to jars, food, and their enemies in a definite manner. In each of these simple cells there is no structure which can be compared to the nerve cells or brain of higher animals.¹ The ability to respond to stimuli in Protozoa seems to be a condition that is present in the whole protoplasm of the cell.

Reproduction. — Paramecia reproduce by fission, *i.e.* an animal divides, producing two; these divide and produce two more. The process of fission goes on indefinitely (Figure 332). Unlike the ameba, these forms encyst very rarely when conditions of life become unfavorable.

259. Gonium. — Gonium is an organism made up of sixteen separate cells held together by a mucilage-like secretion of the cells. Each cell works



FIGURE 332. PARAMECIUM REPRODUCING BY FISSION

independently in getting food, respiring, giving off waste, and reproduction. The colony moves by lashing the water with long protoplasmic threads (flagella), two of which project from each cell. The advantage in rate of movement resulting from the union of cells is illustrated in rowing. Eight men in a large rowing shell can go faster than one man in a single, small shell. In reproduction, the sixteen cells fall apart, and each one grows into a new colony.

260. Volvox. — Volvox is a colony of hundreds of tiny green cells embedded in a hollow gelatinous sphere. Each cell has two flagella. For a time all the cells are alike and share equally in the work of the colony. But in reproduction only a few cells take part. In the simplest method, a few cells grow large and escape into the hollow sphere. There, they divide and grow into new

¹ There have been described in paramecia some special nerve-like fibers which may assist in coördination.

colonies. Finally, the mother colony breaks, and the daughter colonies escape.

The more complex method is like the reproduction of higher animals. Certain cells in the colony grow large and escape into the hollow sphere. They are the *egg cells*. Other cells of the colony enlarge and divide into large numbers of slender, free-swimming cells called *sperm cells*. The sperm cells escape into the hollow sphere and swim about. One sperm enters an egg cell and unites with it, forming a single cell, the *fertilized egg cell*, which can develop a new colony. Both *gonium* and *volvox* have a special interest for us in that they show characteristics of both plants and animals.

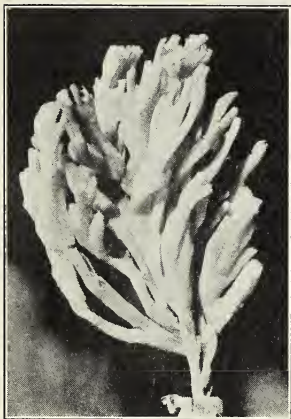


FIGURE 333. A BRANCHING SPONGE

A sponge is a simple animal composed of many cells. In them division of labor is carried out in a more complex way than in *gonium* and *volvox*. Simple sponges have a body in the form of a hollow cylinder.

SUMMARY

Hydra represents a group of animals that have two tissues, but no complex organs for performing their life processes. Fungi, plants of simple organization, cannot make their own food, so live upon that made by other organisms, either while it is living or after it is dead, and this habit is termed either parasitic or saprophytic. Yeast is a unicellular fungus that lives on sugar, releasing carbon dioxide and alcohol in the process. *Pleurococcus*, a unicellular plant, is able to make its own food, but can live a long time under unfavorable conditions. The *ameba* is the simplest known animal able to change its shape readily. It takes in food at no fixed region. The *paramecium* is more highly organized, and more active than the *ameba* and is sometimes described as one of the giants among Protozoa. *Gonium* is a small colony of cells, each of which carries on the vital processes independently of the others. *Volvox* is a large colony in the form of a hollow sphere that has some specialization among its cells.

QUESTIONS

In what ways is hydra more simple in structure than animals previously studied? In what respects is it a higher organism than unicellular organisms? What is the peculiarity of fungi? What is their economic importance? What uses are made of yeast? Describe pleurococcus, ameba, paramecium. What is an egg? a sperm?

SPECIAL TOPICS FOR DISCUSSION

1. Try to find out which characteristics of volvox resemble those of animals, and which resemble those of plants.
2. Make a list of other organisms on the border line between the two kingdoms.

REFERENCES

Hegner, *College Zoölogy*, pages 50-60, The Macmillan Company
Smallwood, *Textbook of Biology*, pages 137-150, The Macmillan Company
Wieman, *General Zoölogy*, pages 40-44, McGraw Hill Publishing Company

David T. ...

CHAPTER XXV

BACTERIA — THE SMALLEST AND SIMPLEST PLANTS

*Why has not man a microscopic eye?
For this plain reason, man is not a fly.
Say, what the use, were finer optics given,
T'inspect a mite, not comprehend the heaven.*

— POPE

261. Introduction. — Bacteria are the smallest of all plants — so small that they can be seen singly only by the aid of a powerful microscope. We do not know all about their life processes, but we have learned much about their effect. We constantly hear about these plants, either under their correct name, *bacteria*, or

under the name *germs* or *microbes*. Two incorrect ideas concerning bacteria are prevalent, — one, that bacteria are animals, and the other, that all are harmful. It is definitely known that bacteria are plants; that small as they are, they are among the most important plants in the world; that most of them are helpful, and only a few harmful.

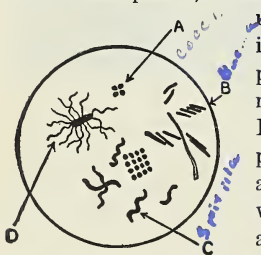


FIGURE 334. FORMS OF BACTERIA

A, cocci; B, bacilli; C, spirilla; D, bacillus with flagella.

262. Appearance of Bacteria. — Bacteria are grouped into three classes according to their shape: (1) round (the cocci); (2) rod-shaped (the bacilli); (3) those that are shaped like a corkscrew (the spirilla). The spirilla and the bacilli often have on one or both ends tiny thread-like hairs called *flagella* by which they move, giving the first observers reason to think that they were animals.

Fifteen hundred of the rod-shaped bacteria hardly reach across the head of a pin. When bacteria are grown in the proper kind of substance, there are so many in a cluster that they appear as tiny spots or points, often tinged with a faint color. When seen under the microscope, individual bacteria are clear, almost transparent, colorless, and often have a bright, shining spot (the spore) on the inside.

263. Conditions of Growth. — Bacteria are everywhere — in the air as invisible dust, in the upper layers of the soil, and in water.

Like all other plants, bacteria must have all the proper conditions before they can grow and multiply. Their food is chiefly plant or animal matter, but they cannot make use of food except in the presence of warmth and moisture, and most of them require oxygen in addition, which they get from the surrounding air.

When food, air, warmth, or moisture is not sufficient, bacteria cease to grow and go into a resting state (encystment). That is, they change their form, and surround themselves with a substance which protects the soft protoplasm from being harmed by freezing, heating, or drying.

264. Life Processes. — In the preparation of their food bacteria break up organic substances absorbed through their walls; that is, they decompose them, causing the condition known as decay. They use some of the material resulting from decay, some they set free in the air, and the remainder is left on the earth and is used by more complex plants. In changing dead matter, — plants, leaves, and animals, — to a form which again becomes a part of the earth, bacteria perform a service vital to man and to the whole world of plants and animals.

Reproduction occurs in bacteria through simple fission. Sometimes bacteria break entirely apart, while in other cases they remain connected, forming a chain. Under favorable conditions each cell can grow to full size in half an hour and be ready to divide again. It is this ability to multiply rapidly which makes them of such great importance, for a few hundred bacteria, even harmful ones, could produce little effect.

265. How Bacteria Do Harm to Living Things. — There are three ways in which bacteria may harm other organisms: (1) by their mere presence in large numbers causing the blocking of fibro-vascular vessels in plants and of small blood vessels in animals; (2) by living on the substance of the organism itself, as in the actively parasitic forms which live in vital organs; and (3) by the effect of some of their secretions, known as *toxins*, which poison the host and even the bacteria themselves, when there is a large quantity of it.

266. How Bacteria Help Us. — In the process of growth, bacteria produce two kinds of substances, *enzymes* and *toxins*. Enzymes produce fermentation, a breaking-up process of which man makes use to secure certain flavors and odors, as well as to soften hard materials. Bacteria, by making enzymes, give flavor to such foods as cheese and butter. Such bacteria are classed as helpful, as are those which gather nitrogen for the plants of the bean family. Examples of other helpful bacteria are those that make it possible for man to use sponges by ridding them of the soft, slimy substance with which they are filled when alive, and those that soften the useless parts of the flax plant so that the rest of it may be separated and made into linen.

267. Soil Bacteria. — The surface soil, especially if it is rich in organic matter, contains many kinds of bacteria; but at a depth of ten feet they have usually become scarce. Ordinary earth may yield from 10,000 to 100,000,000 in a gram if it has become polluted. Soils which have not been cultivated have fewer. The condition which really determines how many bacteria will be found in the soil is the amount of organic matter it contains.

The soil bacteria do a most important work in breaking down parts of dead plants and animals and in enriching the soil so that living plants can find more nourishment in it.

The roots of such plants as the clover and the pea (leguminous plants) become infested with certain bacteria found in the soil. These bacteria form bunches or nodules on the roots in which they live. Thus protected, they gather nitrogen from the air,

use what they need, and store up the rest. This surplus is used by leguminous plants in making protein, part of which is found in the body of the plant, and part in the seeds. When the seeds are used as food, both man and animals secure the protein which they need. When the plants die, they leave the soil richer in nitrogen in a form that can be used by plants that do not have the help of the bacteria to gather it. So valuable is this form of fertilizer that in some cases leguminous crops are raised and plowed under for the sake of the nitrogen in them, this being called "green manuring," a practice which was carried on for a long time before the reason for its value was learned.

268. Vital Processes. — In many respects the vital processes of bacteria are similar to those of other unicellular organisms. They differ, however, in the ability of some of them to use raw material for food, in the effect of some of their excretions on themselves and other organisms, and in being able to obtain oxygen for respiration from other sources than the air. Such use as we are able to make of helpful bacteria and such control as we have of harmful ones depends on our knowledge of their habits. If we can control conditions, we can hasten or retard growth or prevent it altogether. Bacteria, the lowliest form of life, make the closest connection with non-living, inorganic substances. The significance of this is shown in tracing the cycles made by such elementary substances as oxygen, nitrogen, hydrogen, and carbon.

269. Oxygen, Carbon, and Nitrogen Cycles. — Food is consumed to build up protoplasm that it may be torn down by unit-



FIGURE 335. NODULES ON ROOTS OF PEANUT PLANT

ing with oxygen in the process of oxidation or slow combustion and to release energy in the form of warmth or motion or both. During this process, carbon dioxide is set free. Some kinds of bacteria, instead of using organic substances for food, can release energy by breaking down iron and sulfur. Bacteria that can live shut away from air are known as anaerobic bacteria, while those that depend on air are called aerobic. *Define*

The Oxygen Cycle. — We shall first review the cycle of oxygen. This important element is taken into the body and is used in oxidation. There results a waste product, carbon dioxide.

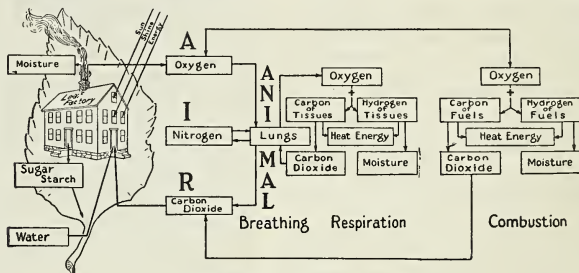


FIGURE 336. OXYGEN CYCLE

Trace the cycle of oxygen in the leaf, in breathing by animals, in animal respiration, and in combustion. How does each differ from the others? What similarities do you find?

Carbon dioxide is taken up by the green plant and the carbon becomes a part of the starch, while the oxygen is set free and escapes into the air ready to be used again by some organism in respiration. Oxygen can go through this series of changes an endless number of times without losing any of its properties. It is thus said to go in a cycle or circle in its relation to living things.

The Carbon Cycle. — The carbon which is a part of starch remains in this food until some organism utilizes it in respiration. The organism then sets it free as a waste product in carbon dioxide, to be later built up into starch in photosynthesis. The scientists who have tried to discover just which elements are in living protoplasm all agree that carbon is present in large amounts.

It constitutes about 72% of our own bodies. The carbon that is a part of the living protoplasm remains in this relation for a variable length of time, being finally released when the protoplasm dies; in this way it differs from oxygen. There is thus a carbon cycle just as there is an oxygen cycle.

The Nitrogen Cycle. — Nitrogen is another important element found whenever organic matter is analyzed. Living things cannot utilize nitrogen unless it is in a complex form. Animals require proteins which are very complex. These proteins are manufactured by green plants. When an organism dies, the nitrogen compounds are made simpler by the action of bacteria. Green plants take up nitrates (simple nitrogen compounds) and store the nitrogen away in proteins.

Undoubtedly many of the compounds built up by the animal and plant would automatically break down after death, yet bacteria hasten the process. In this process of decay, the compounds are almost completely broken down and the result is that the nitrogen has now become so simple (simpler than nitrates) that green plants cannot utilize it. The group of bacteria (denitrifying bacteria) which change nitrates into gaseous nitrogen allow the nitrogen to escape into the air, thus putting it beyond the reach of green plants. Then there come the nitrogen-fixing bacteria, which rescue this gaseous nitrogen from the air and unite it with other elements suitable for green plants to use.

The nitrogen cycle is thus very complex in comparison with the oxygen cycle, and it is no wonder that the complete story remained untold for many years. Scientists had to learn a great deal about the life of bacteria before they understood how important a part they play in the life of all of the higher organisms, including man.

It is possible, by governing conditions, to secure the good effects of bacteria, and to prevent many of the bad effects. A brief definition of the commonest terms used in working with bacteria will help you to understand what you read.

Aseptic, free from harmful bacteria, especially those that are the cause of some particular disease. Accomplished by fumigation, by washing with chemicals, etc.

Sterile, lacking all bacteria. ^{Boiling} Accomplished by using heat or chemicals. Applications: preserving fruit, meat, etc.

270. Food Preservation. — Because milk is a perfect food, bacteria multiply very rapidly in it. By heating it to 60°C for twenty minutes or to a higher degree for a shorter time, most of the harmful bacteria are killed. The use of ice to keep it cold will prevent the growth of others that may get into it. The process of heating it is called pasteurization. The bacteria that

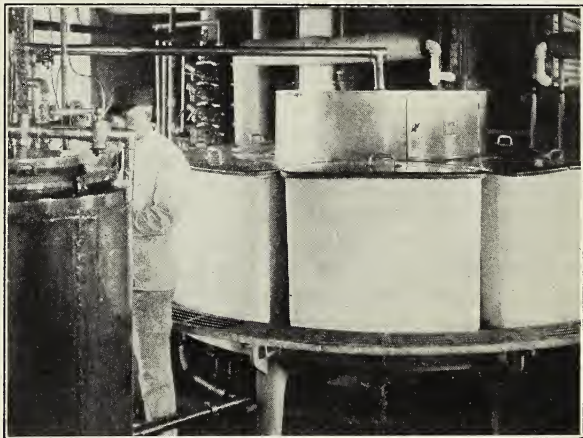
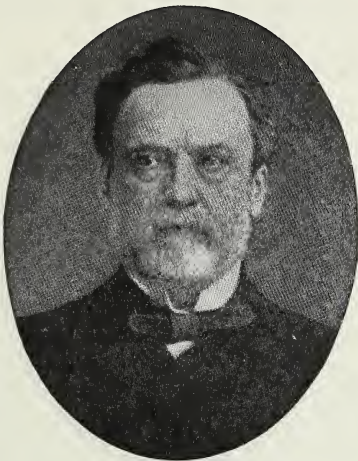


FIGURE 337. PASTEURIZING TANKS

Here milk is heated to 145° to destroy any possible disease germs.

cause milk to sour are not harmful, but they change the taste of milk so that it is unpalatable to many persons. Ice cream should not be kept too long, or exposed to the open air, as either may give harmful bacteria a chance to grow in it. The more we learn about bacteria, the more we can make use of the helpful ones and avoid the harm that the other kind do.

Any device which will check the activity of bacterial growth will delay spoiling. The problem of keeping our food free from decay becomes increasingly difficult with the increase in popula-



LOUIS PASTEUR (1822-1895). This distinguished Frenchman was trained as a chemist and made a notable contribution to that field of knowledge before he began to study germs. Soon after the invention of the microscope, germs were found in water and the theory of spontaneous generation of life aroused new interest. Pasteur showed that there is no spontaneous origin of life.

Pasteur attained his greatest success in his study of microscopic organisms. His first success was in the study of fermentation and diseases of wines. This was followed by his investigation of the silk-worm plague. He then began the study of the prevention of disease, making a repeated series of pure cultures which rendered the germ less poisonous. This weakened germ he injected into animals to protect them from disease. He first tried this experiment with fowl cholera; then with splenic fever; and after many years of experimentation he was successful in preventing hydrophobia in a human being who had been bitten by a mad dog.

The Pasteur Institute was established in 1888. More than thirty similar institutes have since been established in different parts of the world. Pasteur probably made more discoveries which were directly beneficial to human welfare than any other man.



ANTONY VAN LEEUWENHOEK (1632-1723). This noted Hollander had an easy, prosperous life (his parents were doubtless wealthy), and devoted himself entirely to science.

Leeuwenhoek's first publication on microscopic objects appeared when he was forty-one years old. He became fascinated with the making of crude microscopes and possessed no less than 247 complete microscopes with many additional lenses. (See page 50.)

In 1686, he observed the minute circulation of the blood and demonstrated the capillary connection between veins and arteries.

As you see the demonstration of capillary circulation in the web of the foot of the frog, you should have before you his enthusiastic description of the circulation in the lung of the frog. The first sentence is as follows: "A sight presented itself more delightful than any mine eyes had ever beheld: for here I discovered more than fifty circulations of the blood in different places, while the animal lay quiet in the water, and I could bring it before my microscope to my wish."

tion. The following are some of the methods used in preserving food :

Canning. — Canning is a simple plan for keeping bacteria away from food products.

The process involves, first, removing the bacteria already present in the food ; and second, preventing all other bacteria from gaining access to it later. The first need is met by heating the food to a sufficiently high temperature to destroy the bacteria ; the second is met by hermetically sealing the food in a can or jar while it is still hot.

Preservatives. — Preservatives are of two kinds, poisonous and non-poisonous. The non-poisonous preservatives are sugar, salt, vinegar, and spices. The use of such preservatives is perfectly proper and their success in keeping bacteria from growing is due to the fact that bacteria do not grow in solutions containing these substances. Condensed milk contains 30% to 40% cane sugar. Jellies are preserved from bacterial action by the large amount of sugar which they contain. Raisins, figs, and dates are preserved partly by drying and partly by the presence of sugar. These three fruits contain so much sugar that it is not necessary to add sugar while drying them.

Salt, one of the commonest and least harmful of preservatives, is used in a variety of products, of which fat pork, corned beef, hams, and fish are the most common.

Drying. — All bacteria require a considerable amount of moisture for their life processes and cannot develop in moderately dry food. Nature has adopted this method of preserving the seeds of most plants. We find that the ripened seeds of grasses, wheat, corn, and many other plants are dry. In the past few years a whole new industry has grown up around this principle of drying, with dried milk as one of the best examples. Many fruits, besides prunes and apricots, can be preserved by drying.

Cold. — Low temperatures, as in cold storage refrigerators, or even freezing may be used. Bacteria cannot grow at extremely low temperatures and the food can be preserved indefinitely.

However, this method does not destroy the bacteria that are in the food. It simply checks their growth.

271. Pioneers in the Study of Bacteria. — The inventor of the microscope should be placed at the head of the list of men who made the study of bacteria possible, for without this instrument we should not know that such plants exist. We do not know who the actual inventor was, but the microscope was little more than a toy until it was improved by a Dutch naturalist, Leeuwenhoek (see page 50), in the latter part of the seventeenth



FIGURE 338. CULTURES OF MILK BACTERIA

The culture on the left was made from milk six hours old that had been kept in a clean bottle in a refrigerator. The bottle was then left for six hours in a warm place; the same amount of milk from it gave the culture on the right.

century. Next in the study of bacteria comes Pasteur, who discovered and studied them in their relation to the souring of milk and in other fermentations. Then comes Koch, who discovered a way of separating bacteria so that each kind could be studied by itself, a method called getting a "pure culture." He also invented the tuberculin test for tuberculosis in cattle. Most of the facts about bacteria have been secured during the past fifty years, since men have learned how to prepare them for study.

272. Healthy Bodies and Bacteria. — So much has been said about harmful bacteria that a word of caution is needed. Two facts should make us take a sane view of the situation: (1) for



ROBERT KOCH (1843-1910) attained great renown when in 1882 he discovered the germ which causes tuberculosis. In the next year he announced that he had found the germ of Asiatic cholera. He advanced the science of disease by making other important discoveries. For some time before his death, he was the director of the Institute for Infectious Diseases in Berlin.

In all of his investigations he applied strictly scientific methods, some of which have become a regular part of the procedure used in studying a germ disease. Four steps must be taken before one can be certain that the cause of a germ disease has been discovered. These are: first, a microscopic organism of a particular type must be found in abundance in the blood or tissues of the sick animal; second, a pure culture must be made of the suspected organism; third, this pure culture, when introduced into the body of a similar animal, must produce the same disease; and, fourth, there must then be found in the blood or tissues of the diseased animal large numbers of this introduced organism.

•

100

every harmful bacterium there are thousands of helpful ones; and (2) harmful ones cannot do their work, or even live, in a perfectly healthy body, for such a body is constantly preparing a substance (*antitoxin*) which neutralizes the bacterial poison (*toxin*).

SUMMARY

The smallest and simplest of all plants are the bacteria. Most of them are helpful, ridding the earth of waste material, giving flavor to food, gathering nitrogen from the air for plants. They are found everywhere, unless special pains have been taken to remove them. The harmful bacteria during their growth secrete a poisonous substance, toxin. When there are enough bacteria present to make a large quantity of toxin, the animal or plant containing them is made ill. Some bacteria, especially in the resting state, can bear freezing or boiling without being killed.

Milk, one of the most important articles of food, is a possible source of danger from harmful bacteria, which may get into it in various ways.

The decay of foods is caused by the growth of different kinds of bacteria. If means are taken to prevent such growth, the food may be preserved. In order to make anything "keep," it is necessary to kill all the bacteria, to put into it a preservative, a substance in which the bacteria cannot grow, to remove most of the water, or to keep it very cold.

The men who did the most to make the study of bacteria possible were Leeuwenhoek, who improved the microscope; Pasteur, who discovered bacteria in milk; and Koch, who found the way to make a pure culture and to test cows for tuberculosis. Many students are devoting their lives to the study of the various bacteria.

QUESTIONS

How can food be protected from harmful bacteria? In what respects are bacteria harmful to milk? in what respects helpful? Why are a few harmful bacteria not injurious in a healthy body? If one bacterium divides every half hour, and all live, how many will there be at the end of twenty-four hours? (Solve by arithmetic or by algebra.) Why does an apple with a broken skin decay more rapidly than one in which the skin is not broken? When should one not put ice into water to cool it?

SPECIAL TOPICS FOR DISCUSSION

1. What are the best conditions for the growth of bacteria?
2. Which will spoil first, watery meat, ham, or dried beef? Explain.
3. Discuss the relation of canning and refrigeration to bacteria.

4. What is the work of the milk inspector?
5. What part do bacteria play in agriculture?
6. Who are some of the men who have contributed most to our knowledge of bacteria?
7. What is the relation of bacteria to butter making, tanning of leather, and bread making?
8. What are the various methods that have been adopted to prevent the growth of bacteria other than those mentioned in topic 3?

REFERENCES

- Buchanan and Buchanan, *Bacteriology*, pages 15-59, The Macmillan Company (1930)
- Conn, *The Story of Germ Life*, D. Appleton and Company
- De Kruif, *Microbe Hunters*, Harcourt, Brace and Company
- Greaves, *Elementary Bacteriology*, pages 17-88, W. B. Saunders Company (1932)
- Jordan, *A Textbook of General Biology*, pages 1-23, 136-148, W. B. Saunders Company (1931)
- Snyder, *General Science*, pages 209-218, Allyn and Bacon
- U. S. Bulletin No. 56, Hygienic Laboratory Bulletin, *Milk and Its Relation to Public Health*
- Vallery-Radot, *The Life of Pasteur*, Doubleday, Doran
- Woodhead, *Bacteria and Their Products*, Charles Scribner's Sons

LIFE PROCESSES

In this series of plates is shown, beginning with the simplest and proceeding to the higher forms, the organs by means of which plants and animals perform the vital functions. The diagrams are intended to help you make a comprehensive review of each of these processes.

In all drawings involving internal detail, the outline of the animal is done in broken or dotted lines, the particular system of organs to be stressed in solid lines. Plant drawings and drawings showing only exterior features, habitat, locomotion, have all lines solid. Where necessary, direction is indicated by the use of arrows.

Each drawing is keyed in the legend beneath the diagram.

On the page facing each plate are a descriptive summary and questions on the subject matter.

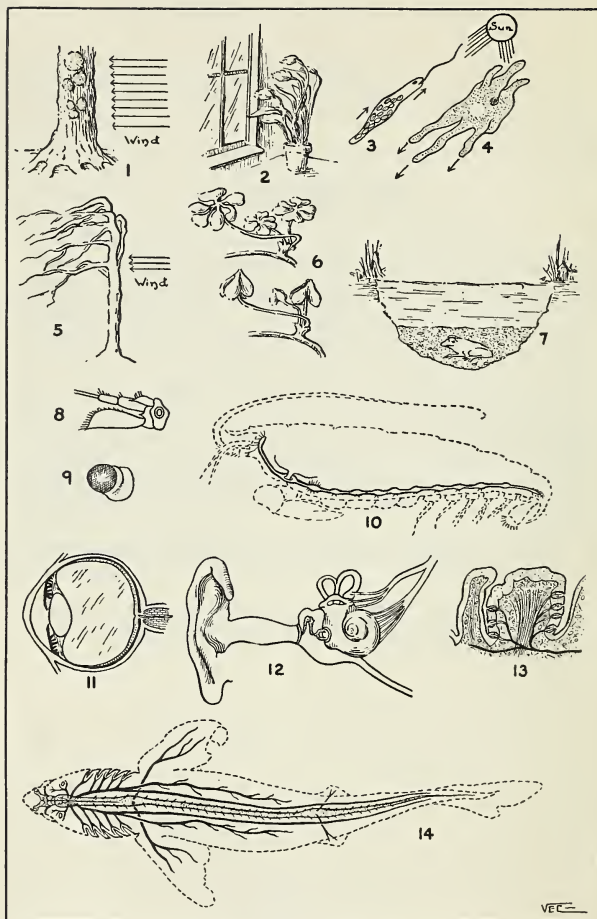


FIGURE 339. SENSATION

1, pleurococcus; 2, potted plant; 3, euglena; 4, ameba; 5, trees distorted by wind; 6, oxalis; 7, hibernating frog; 8, "ear" of crayfish; 9, eye of crayfish; 10, crayfish; 11, human eye; 12, human ear; 13, taste buds of rabbit; 14, dog fish.

SENSATION (IRRITABILITY)

1. Pleurococcus grows on the side of the tree away from the wind.
2. Plants grow towards the light.
- 3, 4. Euglena moves towards the light, ameba away from it.
5. Trees are permanently bent by constant wind in the same direction.
6. Oxalis opens its leaves in the light and folds them in the dark.
7. The frog buries itself in the bottom of a pond when cold weather comes.
8. The ear of a crayfish is a simple organ on the antenna.
9. The eye of a crayfish is on a stalk and movable.
10. The nervous system of the crayfish is on the floor of its abdomen.
11. The eye of a vertebrate is a complex organ, efficient under varied conditions.
12. The human ear has a complicated set of apparatus for gathering and conducting vibrations.
13. Taste is more highly developed in vertebrates than in lower animals. They are limited to definite portions of the tongue.
14. The nervous system of vertebrates is on the dorsal surface. It has special organs highly developed to interpret the environment of the animal.

QUESTIONS

1. What kind of changes are taking place in the surroundings of the organisms listed under statements 1-6 above?
2. What conditions force the frog to take this habitat?
3. What special adaptations have animals that help them to appreciate changes in their environment?
4. What problems have been solved by the eye? ear? taste bud?
5. What is the use of the nerves?
6. How many kinds of nerves are there?
7. What is the relation of nerves to sense organs? to muscles?
8. What are some of the changes that have taken place in animals you have studied?
9. Does the study of sensation help you to explain why one animal is considered higher than another?

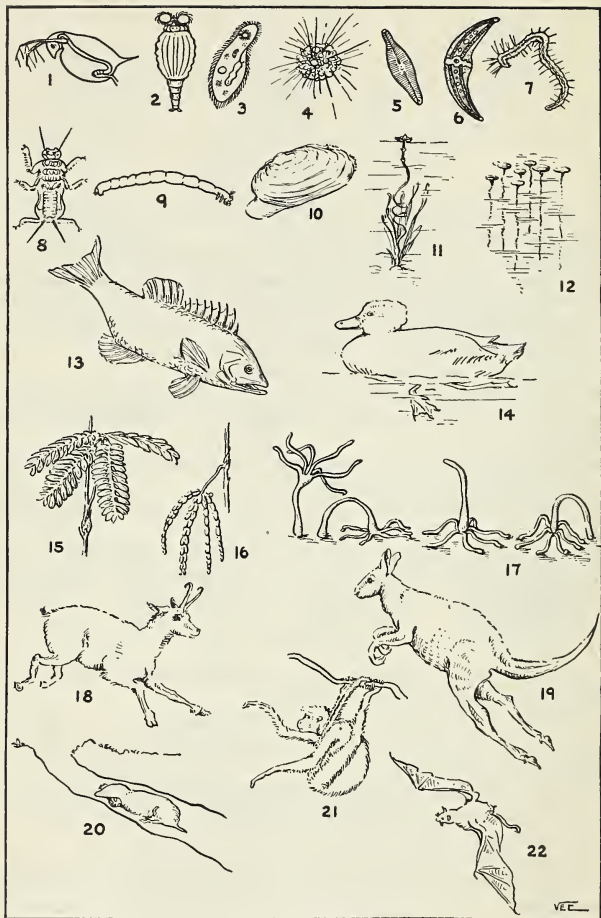


FIGURE 340. MOTION

1, Daphnia; 2, rotifer; 3, paramecium; 4, Heliozoan; 5, diatom; 6, desmid; 7, annelid; 8, stone-fly nymph; 9, larva of Diptera; 10, clam; 11, an aquatic plant; 12, a pond weed; 13, bass; 14, duck; 15, mimosa erect; 16, mimosa drooping; 17, hydra, 4 views; 18, chamois; 19, kangaroo; 20, mole; 21, monkey; 22, bat.

MOTION

1. *Daphnia* (a crustacean) swims by means of feathery appendages.
2. Rotifer (a minute aquatic animal) moves by cilia and tail.
3. *Paramecium* moves by the vibrations of cilia which cover its body.
4. Heliozoan (a fresh-water Protozoan) moves by creeping about on the tips of the projections.
5. Diatoms move. No one knows how.
6. Desmids change their shape.
7. Annelid (a worm) has bristles on each segment to aid in movement.
8. Fringes on the legs of the nymph of stone-fly enable it to swim.
9. Chironomous *Diptera* larva loops along by attaching the legs in front and the rear appendages close to them, then repeating.
10. Clam pushes itself along by thrusting its muscular "foot" into the sand or mud.
11. *Vallisneria* (an aquatic plant) coils its stem to pull its blossom under water after it has been pollinated.
12. *Potamogeton* (a pond weed) simply floats and moves with the water.
13. Fins and a strong tail enable the fish to swim rapidly.
14. The duck propels itself in water by means of its webbed feet.
- 15, 16. *Mimosa*, undisturbed. When touched, it gives a little shiver, folds its leaves together, and lets the petiole droop, as in 16.
17. *Hydra* turns somersaults.
18. The chamois has long slender legs for running.
19. The kangaroo has long, strong hind legs for leaping.
20. The mole can run swiftly besides using its front feet for digging.
21. The monkey uses its tail as well as its hands and feet in climbing.
22. The hands and arms of a bat are modified into a wing-like appendage.

QUESTIONS

Study the diagrams.

1. Which of the organisms in the first row have no visible organs for locomotion? Which have organs for locomotion and other purposes too? What are they?
2. Of the organisms in the second row, which could be stimulated to move by a touch? Why not the others?
3. What are some of the things a duck can do that a fish cannot? Why?
4. Does any other stimulus than touch affect *mimosa*? (15)
5. What other use have the tentacles of *hydra*?
6. How does running differ from leaping? Name animals that do both, and those that do one or the other only.
7. What other uses of its legs and tail does the monkey make?
8. Can the mole run better in a burrow or out of one? Explain.
9. How does the "wing" of a bat differ from that of a bird?

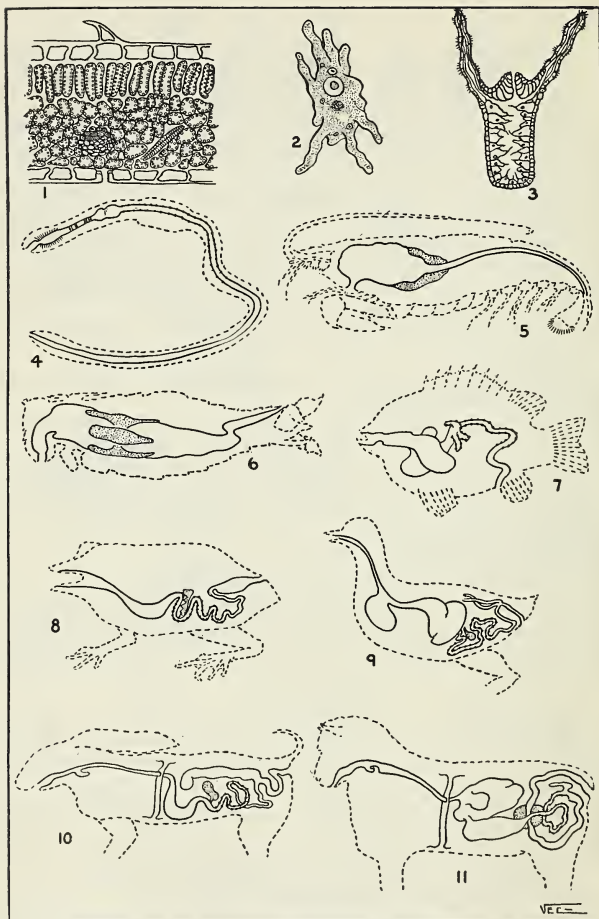


FIGURE 341. NUTRITION

1 portion of leaf; 2, ameba; 3, hydra; 4, earthworm; 5, crayfish; 6, locust;
7, fish; 8, frog; 9, bird; 10, rabbit; 11, sheep.

NUTRITION

1. Food is made only in the cells of plants that contain chloroplasts. Plants use part of the food they make.

2. The ameba digests its food in food vacuoles.

3. The hydra takes its food into its central cavity to digest it.

4. The earthworm has a tubular digestive system, of definite parts, with simple digestive glands.

5. The crayfish has a large stomach, with more complex glands.

6. The locust has a large stomach, short intestine, and large glands.

7. The fish has a branched stomach and a curved intestine.

8. The frog has stomach, coiled intestine, pancreas near stomach, and cloaca.

9. A bird has crop, gizzard, long intestine, and two branches on it.

10. A rabbit has salivary glands, simple stomach beyond the diaphragm, pancreas, and a coiled intestine with one large branch.

11. A sheep has salivary glands, a stomach in four divisions, pancreas, more difference in size in regions of the intestine, and one short branch.

QUESTIONS

Study the diagrams with a view to answering the following questions :

1. Why is the leaf so important to the plant? to the animal organisms?

2. Where does digestion take place in the leaf?

3. What use is made of the digested food? of unused food?

4. What organisms does ameba use for food?

5. What is the food of hydra? How obtained? Where digested?

6. In what three ways is the digestive system of earthworm different from that of hydra?

7. What is the peculiarity of the stomach of crayfish?

8. Compare and contrast stomach and intestine of crayfish and locust.

What new features are found in digestive system of fish?

9. Locate the pancreas in animals that have it.

10. Which animals have salivary glands? diaphragms?

11. Which ones have large and small intestine?

12. Which have teeth for holding food? for chewing food?

13. What other questions occur to you?

14. Intestinal glands are represented by dots. Which animals have them?

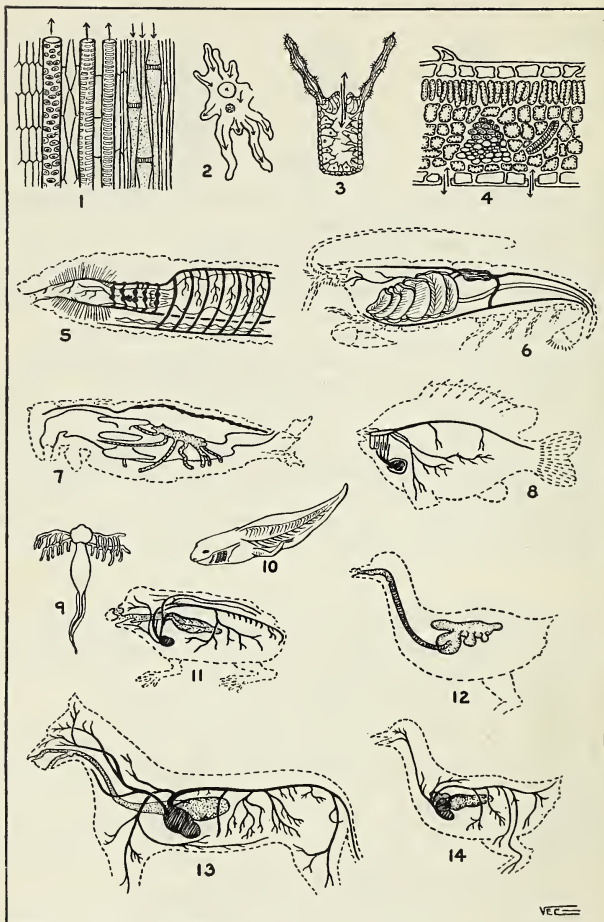


FIGURE 342. RESPIRATION AND CIRCULATION

1, Portion of stem of plant; 2, ameba; 3, hydra; 4, portion of plant leaf; 5, anterior end of earthworm; 6, crayfish; 7, locust; 8, fish; 9, frog tadpole; 10, frog tadpole; 11, frog; 12, bird; 13, dog; 14, bird.

RESPIRATION AND CIRCULATION

1. Water, absorbed by the roots of a plant, passes up through the vessels of the xylem. Digested food passes down through phloëm vessels.
2. Circulation of protoplasm in ameba is helped by the motion of the animal. The flow is towards and into the pseudopodia.
3. In hydra the motions of the animal help water containing food to pass in and out through the mouth.
4. Every live cell respire. Air passes in through the stomata, waste gases and water vapor pass out. Veins carry water to all parts of the leaf.
5. Earthworm has blood vessels and heart, but no lungs or gills.
6. The blood vessels of crayfish are closely connected with the gills.
7. In locust there is not a close connection between the circulatory system and the respiratory. The dorsal blood vessel is shown by a black line; the principal tracheæ are dotted.
8. In fishes, the blood is pumped to the gills.
9. Tadpoles have external gills in their early stages. There the blood gets its oxygen.
10. Internal gills take the place of external ones as the tadpole grows.
11. The mature frog has simple lungs well supplied with blood vessels. In the diagram, the respiratory system is dotted, the arteries black lines.
12. Birds have air sacs in addition to lungs. These have no special blood vessels.
13. Note the greater number of arteries in the dog than in the fish and crayfish. The respiratory system is dotted, the arteries black lines.
14. The lungs of birds are richly supplied with blood vessels. The lung is the dotted area, the arteries the black lines.

QUESTIONS

1. How do ameba and hydra respire?
2. What do veins do for a leaf? How can you prove that a leaf performs respiration? circulation?
3. How does the earthworm get its oxygen? What functions does circulation perform?
4. Why is not the circulatory system of a locust as closely connected with the respiratory as in most animals?
5. Compare and contrast the two systems in crayfish and fish.
6. Why are different organs necessary in the various stages of the life of a frog?
7. What is unique about the respiratory system of a bird?
8. Which of these organisms have corpuscles in the blood?
9. How does the circulatory fluid of plants differ from that of animals?
10. What organs besides lungs and gills need a rich supply of blood vessels? Why, in each case?

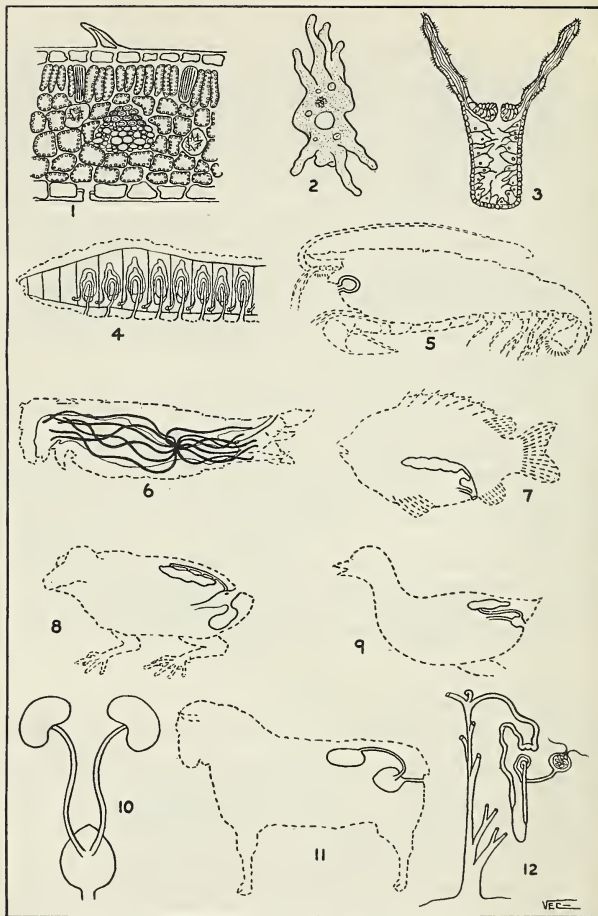


FIGURE 343. EXCRETION

1, portion of leaf; 2, ameba; 3, hydra; 4, earthworm; 5, crayfish; 6, locust; 7, fish; 8, frog; 9, bird; 10, excretory system of mammal; 11, excretory system of sheep; 12, nephridial system of mammal.

EXCRETION

1. Plants store their mineral wastes in the form of crystals of various shapes.
2. Ameba gets rid of liquid waste by expelling it through the contractile vacuole.
3. Hydra uses its mouth for taking in food and expelling wastes.
4. Earthworm has a pair of nephridia in each segment except the first 3 or 4 that collect the wastes from the one in front of it.
5. The crayfish has a pair of small organs of excretion in the anterior part of its body, the green glands.
6. The Malpighian tubules of the locust are widely distributed throughout its body.
7. In fish the excretory organ is the kidney. It is compact, near the center of the body, is near the small bladder, and has a short ureter. There are two kidneys.
8. In frog, the kidneys are close to the backbone, have longer ureters, and open into a bladder connected with the cloaca.
9. A bird has kidneys near the backbone, but no bladder. The ureters open into the cloaca.
10. The kidneys of mammals are compact, have long ureters, and open into a bladder that is emptied through the urethra.
11. The sheep has a typical urinary system.
12. A kidney consists of numerous units each made up of many separate parts as indicated in the diagram.

QUESTIONS

Study the diagrams.

1. How does a leaf get rid of its wastes other than mineral?
2. Which organism has no special organ for excretion?
3. Which have paired organs? unpaired?
4. Which have the organs of excretion distributed evenly?
5. Which have them in the anterior part of the body? in the posterior?
6. What other organs perform excretion also?

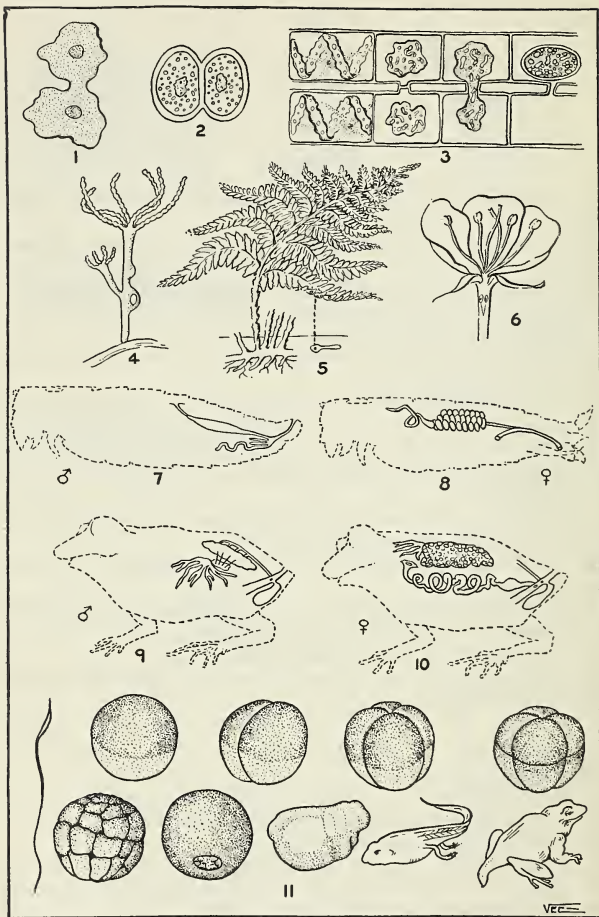


FIGURE 344. REPRODUCTION

1, ameba ; 2, pleurococcus ; 3, spirogyra ; 4, hydra ; 5, fern ; 6, generalized flower ; 7, male locust ; 8, female locust ; 9, male frog ; 10, female frog ; 11, frog development — sperm, 1-celled egg, 2-celled egg, 4-celled egg, 8-celled egg, morula, yolk plug, closed gill plate stage, larva with hind legs, frog with stump of tail.

REPRODUCTION

1, 2. In one-celled plants and animals like ameba and pleurococcus, cell division and reproduction are the same thing. Each organism divides into two of approximately equal size, grows to full size and divides again.

3. Spirogyra has two methods of reproduction, cell division, the cells remaining attached end to end, and the union of two cells in conjugation, these forming a zygote from which a new plant starts.

4. Hydra produces buds, and it also produces eggs and sperms at different times to take part in sexual reproduction.

5. Ferns have the alternation of generations. The green fern is the sporophyte generation, and the tiny body that grows from a spore is the gametophyte or sexual generation.

6. Flowers are the reproductive organs of the plants that bear them. The ovary at the base of the pistil contains egg-cells that are fertilized by sperm cells in the pollen grains, these coming from the stamens.

7. The locust male has a pair of testes, not connected with the excretory system, sacs for storing sperms, and tubes for removing them from the body.

8. In the female locust, the ovary contains the eggs.

9. Each testis of a male frog is attached to the kidney on its side, the sperms passing through the ureters.

10. In the female frog, the ovary contains the eggs. As these leave the ovary they are collected by the oviduct and passed out through the cloaca.

11. The life of a new frog begins with the fertilization of an egg by a long slender sperm. By cell division the egg gradually develops into a tadpole, then into a small frog.

QUESTIONS

1. Which of the organisms represented on this plate reproduce only asexually? which only sexually? which both?

2. What advantages can you think of in the alternation of generations in plants?

3. Mention plants that reproduce by other methods as well as by seeds.

4. With what system is the reproductive most closely associated?

CHAPTER XXVI

ANIMALS AND PLANTS OF THE PAST AND FUTURE

The earth does not know itself in the revolution of years; even the races of man assume various forms in the course of ages. — MANILIUS

273. Old Mother Earth. — Plants and animals must have food to give them form and size and they must have oxygen to give them energy. The source of food and oxygen is the earth, which we must think of as made up of land, water, and air. Part

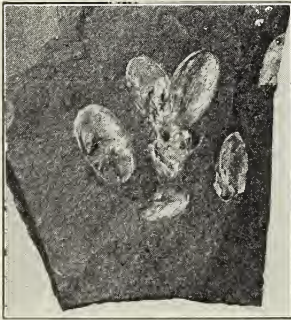


FIGURE 345. FOSSIL REMAINS OF
A SPECIES OF LINGULA

These impressions have been preserved in rock millions of years.

of the land is solid rock and part of it is soil, — sand, clay, and other materials. Some of the land floats in the air as dust and some of it is suspended in the water.

Most of the water is in the oceans, seas, lakes, and rivers but some of it is floating in the air as clouds, fog, or vapor. Considerable water courses through the land in underground streams or gathers below the surface in soil and porous rocks.

stirring is vital to both plants and animals, enabling them to live in widely different places on the earth, in the sea, and in the air. If we examine a plant, we learn that the substances (elements) that compose it came from the air, water, or land, but we find no elements in plants that were not first in the earth. If we

In the water of the oceans and in the land we find air, — land, water, and air being mixed in various ways. This mixing and

examine an animal, we learn that its body contains no elements that were not first in the earth. (Review pages 23-31.) Plants and animals are merely holding in a living form some of the elements that the earth has contributed to them. When they die, the elements return to the earth, and in time these may serve in the body of another plant or animal.

Since the earth is the contributor of all the material portions of plant forms and animal forms, it is fitting to speak of the earth as Old Mother Earth. The earth is, in this sense, the mother of all living things.

274. The Birth of the Earth. — No one *knows* how the earth began, but the following is the theory most generally accepted.



FIGURE 347. AN AMMONITE

This snail-like animal lived more than 150,000,000 years ago. Soon after that time it was exterminated.



FIGURE 346. A LINGULA

This drawing shows the stalk by which it fastens itself to a rock or other support. This animal has a long line of ancestry, running back nearly 500,000,000 years.

In some way a portion of sun was drawn or thrown from its mass. We could call this happening the birth of the earth, which then began to take form as a group of materials by itself. In the beginning the earth was smaller than it is now and was probably molten for a long time. There was no way for life to start on a hot molten earth, but as time went on, the earth began to cool and to assume a more definite shape. Then for millions of years, it attracted other bodies

from space, thus adding to its size and weight. In this way it became several times larger than at first and was able to hold an atmosphere down against its surface. Finally the earth became cool enough for some forms of living things to survive. With the proper elements available and the proper temperature

reached, it is believed that some forms of simple life appeared. These early forms of life used the necessary elements and compounds to form the substance known as protoplasm. Early life and all life since makes itself manifest through the medium of protoplasm.

We assume that the first living protoplasm was in the form of a single cell. Being alive, it could form other cells like itself, that is,

it could reproduce. One cell became two cells under proper conditions of temperature and the presence of food and water.

We may assume also that for a long period of time the forms of life were one-celled only. We gain an idea of the method of reproduction by studying the paramecium or the ameba. One of either of these forms soon develops into thousands in a suitable growing medium (pages 332-335).

Another step upward is shown when the animal or

plant, instead of dividing and separating, divides (forms two cells) but remains joined. Each of these two divides (forms two cells) and remains joined, forming four cells. This continues for a short time in the simpler plants and animals and for a longer time in the higher plants and animals.

We are able to gain an idea of this simple multiplication of plant cells in the spirogyra (Figure 311). Other higher plants like liverworts (Figure 310), mosses (Figure 309), ferns (Figure 307), and flowering plants (Figure 235) show increasing complexity. A similar series of animal forms may also be found.

Life in its simplest form may have started five hundred million or a billion years ago. In any event, it was a long, long time

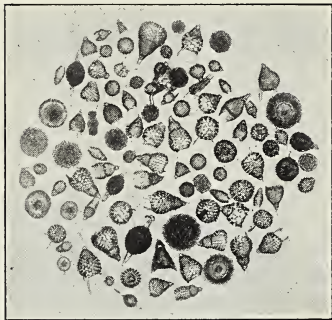


FIGURE 348. RADIOLARIANS

This picture shows the shells of over a hundred species of radiolarians. They are protozoans, and have a great variety of interesting forms.

ago. The earth may have been pulled away from the sun two billion years ago. According to these figures, the earth has been inhabited from one quarter to one half of the time of its existence.

More than half of this period has been given over to one-celled forms. Fossil remains of animal and plant forms of the earliest

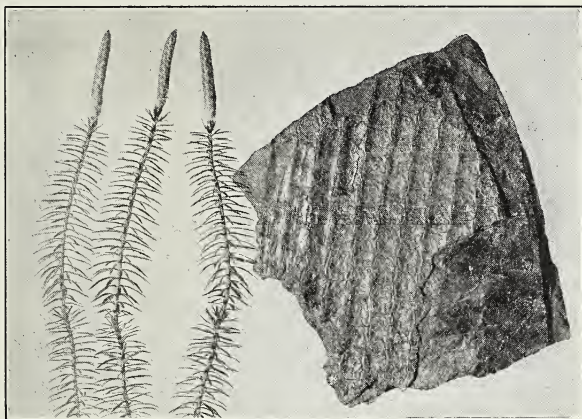


FIGURE 349. CLUB MOSS

At the left is a modern club moss, while at the right is a portion of the fossil stem of one of its early relatives. The modern species is creeping club moss, while its ancestor was a tree, 100 feet in height.

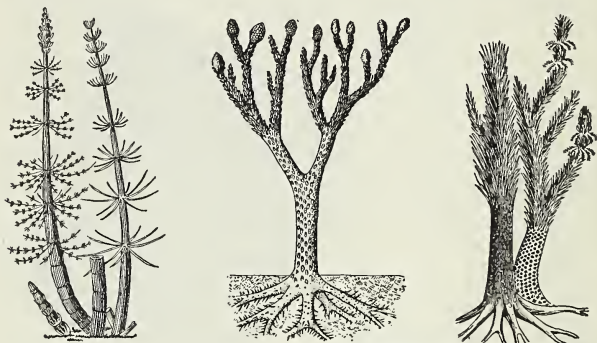
times have not been found, but traces and deposits of carbon, such as graphite, indicate that life was present.

We shall never know from any fossil evidence whether the first living thing was a plant or an animal, but we may assume that it was quite unspecialized. From this elementary form there has been a development in two specialized forms that we call plants and animals. Plants and animals are alike in many ways, and unlike in a few respects.

275. Reckoning Time. — In our legal calendar we say that this is the twentieth century A.D. Our legal calendar starts counting time from the birth of Christ. In describing events

before that time, such as the life span of Aristotle, we say B.C. Of course, most of geologic time would be given as B.C., but it is so remote that it cannot be described exactly by numbers.

Geologists are agreed upon a time in the early history of life on the earth that they call Cambrian. (See page 367.) It was a long period characterized by animals that were invertebrates.



*Adapted from drawings in Pirsson and
Schuchert's Textbook of Geology*

FIGURE 350. PLANTS OF THE PAST
Calamites, Lepidodendron, Sigillaria

There were no birds or mammals or fishes. During this period all plants lived in the water; no trees or plants grew on land. The Cambrian had a rather mild climate; corals thrived even in the polar seas.

The Cambrian is a portion of a much longer geologic time called Paleozoic (early life). The next long stretch of time following the Paleozoic is the Mesozoic (middle life). The last portion includes the time in which we live and is called the Cenozoic (recent life).

You will find wide differences as you read various books that deal with geologic time. The table that we have selected is based upon the rate of change observed in radium-bearing rocks, which at present is regarded as one of the best methods of meas-

ERA	PERIOD	SIGNIFICANCE
<i>Cenozoic</i> 55,000,000 to 65,000,000 years ago	Recent	Domestication of animals. Written records. Dominance of man.
	Pleistocene	Periodic glaciation. Extinction of large mammals. Neanderthal man and Cro-Magnon man.
	Pliocene	Man uses fire and rough tools.
	Miocene	Advance in anthropoids. Culmination of mammals.
	Oligocene	Extinction of early mammals. Early anthropoids.
	Eocene	Primitive monkey, horse, and elephant appear. Increase in number of mammals. Some of them live in tree tops. Modern flora.
<i>Mesozoic</i> 135,000,000 to 175,000,000 years ago	Cretaceous	Advance in mammals. Last of dinosaurs. Rise of flowering plants and modern insects.
	Jurassic	Egg-laying mammals appear. Birds appear with teeth. Great dinosaurs appear. Rich marine fauna.
	Triassic	Rise of dinosaurs. Connecting link between mammals and reptiles appeared. Cycad-like plants.
<i>Paleozoic</i> 350,000,000 to 470,000,000 years ago	Permian	Rise of primitive reptiles.
	Carboniferous	First reptiles appear. Large amphibians. Abundant sharks. Spore-bearing plants
	Devonian	Lungfish. Forests. First amphibians appear. Chain corals disappear.
	Silurian	Primitive sharks appear. Brachiopods.
	Ordovician	Chain corals, starfish, and fish-like animals appear.
	Cambrian	Advance of invertebrates. Trilobites abundant.
<i>Proterozoic</i> 700,000,000 to 1,000,000,000 years ago		Remains of life mostly lacking. Fossil algæ.
<i>Archeozoic</i>		
<i>Total Age of Earth</i> 1,240,000,000 to 1,710,000,000 years	The estimate of the years given in this table is taken from Bulletin #769, United States Geological Survey, by M. Grace Wilmarth. There is still a wide difference of opinion about the exact amount of time that has elapsed in each division, and it is very difficult to find geologists who agree. The important fact is that the earth has existed for a long period of time, but the period when there is the first record of abundance of life is the Cambrian; from then to the present time represents but a small fraction of the entire age of the earth.	

uring the age of the earth. By reflecting upon these enormous spans of time, you realize that the many forms (species) of animals and plants now found living or as fossils have been developed very slowly.

276. The Family Tree of Plants. — Suppose we take an apple tree growing in our backyard and try to trace its ancestors. It came from an apple seed which grew into a small tree. The apple seed from which this tree grew was borne on an apple tree

that was its parent. There were grandparents and great-grandparents of this tree. We could follow back the family history to the time when it was among the first apple trees to appear on the earth. But the first apple trees must have had ancestors that were not apple trees, although we cannot say what they were at this time. These ancestors had earlier ancestors that were quite unlike themselves. Eventually we are led by this form of reasoning to earlier forms of ancestors that become simpler and simpler as we go farther back.

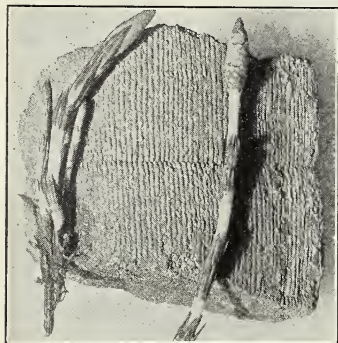


FIGURE 351. HORSETAIL RUSHES

The large ribbed fossil is a section of a rush (Calamite, see Figure 350) that grew to a height of 60 feet or more in the Devonian period. The two plants in front are rushes (*Equisetum arvense*) of today.

We have some support for our line of reasoning in tracing plant remains in rocks. A plant known as horsetail or rush is often found on barren ground. Fossil forms of similar plants, called Calamites, are found in the middle (Devonian) period of the Paleozoic age. (See page 367 and Figures 350 and 351.)

Calamites were large plants, growing to the height of sixty feet with a diameter of a foot. The whorls of leaves of these fossil rushes are sometimes found and are called Annularia (Figure 352). The theory is that the present rush may be a

descendant of the towering rush that lived and flourished millions of years ago, and that competition from other plants has been a factor in stunting or dwarfing the present rush.

Another tree-like form was the *Lepidodendron* (scale tree). (See Figure 350.) These trees grew to the height of one hundred feet. They belong to a group of plants that we find today as creeping vines in damp woods. In other words, the family tree of one of the club mosses would lead back to these tall trees of the Paleozoic age. The rank growth of such plants forms a part of the original stock that has given to the modern world its coal, gas, and oil supply.

277. The Family Tree of Animals. — It is in the period called Pre-Cambrian, the longest of all the periods and the one we know the least about, that are locked the secrets of just how life began, what the earliest forms were, how they moved, how they ate, and how they reproduced. The secrets have been lost in great part because of the destruction of fossil evidence by heat and pressure upon the rocks in which the fossils occurred.

Following the Pre-Cambrian is the Cambrian with a wealth of fossil material. As we move upward through the rock layers that were laid down in these times, we find first appearances of forms of life. By referring to page 367, we note that chain corals appeared in the Ordovician and were exterminated in the Devonian. The starfish first appeared in the Ordovician. Life made little progress during the entire Paleozoic period.

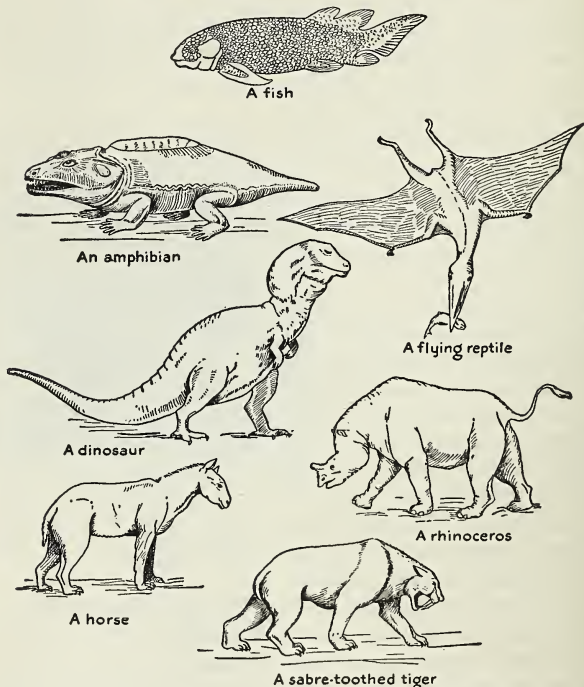
278. Where Fossils Are Found. — Many fossils are from animals that lived in the sea. When they died, they sank to the bottom and were imbedded in the mud. When the mud was



FIGURE 352. ANNULARIA

These fossils are the impressions of the circles of leaves that grew on the younger *Calamites* of the Devonian period.

changed to shale (a rock formation) by long-continued pressure, the imprint of the original animal was left, especially if it was protected by a shell or other hard covering. Later uplifts of the



Adapted from drawings in Pirsson and Schuchert's Textbook of Geology

FIGURE 353. EARLY VERTEBRATES

earth's surface brought these buried shales above sea level where eroding streams exposed them to our gaze. The same sort of process seems to be going on now.

In Siberia, frozen mammoths are found that are thousands of years old. The skin, hair, and internal organs are well

preserved. These animals are fossils preserved by "nature's cold storage."

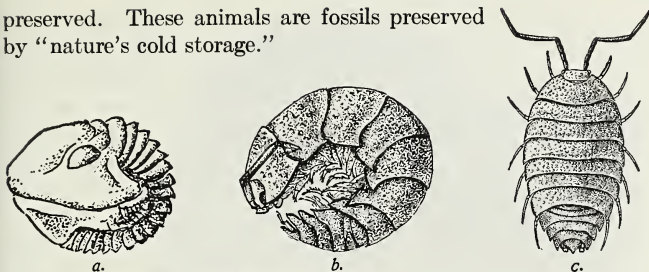


FIGURE 354. AN ANCIENT TRILOBITE AND A LIVING RELATIVE

a, a trilobite folded up in a characteristic pose ; *b*, living form of sowbug (a relative of the trilobite) folded up in a similar manner ; *c*, enlarged dorsal view of sowbug.

Other fossils are found in amber which, in itself, is fossil resin. Ants, flies, mosquitoes, and some plants are caught in the sticky resin and imbedded. This resin changes by evaporation to amber and the forms are so faithfully preserved that the species may be determined. Most of the amber-preserved insects come from the Baltic Sea.

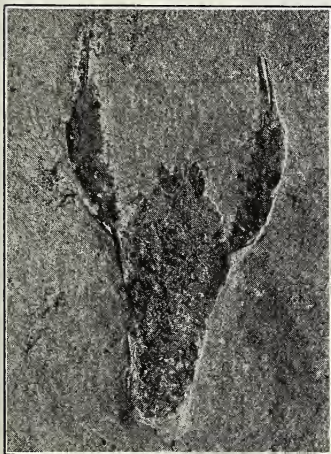


FIGURE 355. AN EARLY LOBSTER

This fossil came from the limestones of Germany. The animal itself lived more than 120,000,000 years ago.

Near Pike's Peak in Colorado is the Florissant Valley, once a lake. The region was volcanic. During eruption, poisonous gases killed various forms of life, some of which fell into the lake. Fine ash fell upon the lake and the insects and other forms of life sank to the bottom of the shallow water. The forms which fell were probably preserved by heat and poison gas

so that decay was prevented. Other eruptions followed, burying the earlier victims deeper until the weight gradually changed the mud to shale. Uplifts brought to view the forms that had died more than a million years before. Some of these fossils are nearly as well preserved as those of the Baltic amber.



FIGURE 356. A FOSSIL FLY

This fossil was preserved in shale in Colorado.

Another method by which fossils of ancient animals have been preserved is found in asphalt beds. These beds were covered by thin soil or wind-blown dust forming a trap. Animals walked along on the thin covering until it broke through and they were mired. Carnivorous animals were perhaps attracted by the out-

cries of the helpless animals, and eventually all sank in the sticky asphalt. Here they have been preserved for thousands of years.

Some animals and plants have been preserved by a process called petrification, by which minerals have gradually replaced the structures of the original plant or animal. Some of the most faithful reproductions of original forms have been produced by this method. Plants generally show better detail of their original shape than animals.

It seems quite unlikely that a new species will unfold before the eyes of any observer for the reason that so much time is involved in their formation. It is true that new species are



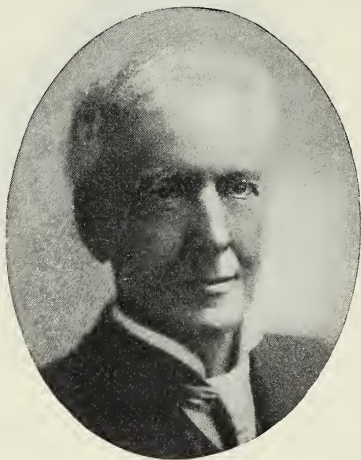
FIGURE 357. A FOSSIL FISH

This fresh-water fish lived about 50,000,000 years ago in what is now Wisconsin.



HENRY FAIRFIELD OSBORN (1857-) was born at Fairfield, Connecticut. After receiving his undergraduate and graduate training at Princeton, he became a teacher of the natural sciences. The field of paleontology had an early fascination for him, and his research turned chiefly to the discovery of fossil mammals. Every visitor to the American Museum of Natural History in New York City has an opportunity to see some of the famous fossils of extinct horses. But Dr. Osborn has not been content merely to make discoveries; he has attempted to offer an explanation of them in his books, *Men of the Old Stone Age* and *The Origin and Evolution of Life*. He has written more than five hundred technical scientific papers.

Even before he became the president of the Museum of Natural History, he had been honored by degrees from American and European universities, and numerous gold medals have been awarded to him. We may well be proud of the distinguished scholarship of this eminent American.



LUTHER BURBANK (1849-1926) is noted for his skill in selecting the most promising young plants, one or two out of hundreds, and carefully rearing them. He made many experiments in plants, producing the thornless cactus, stoneless prunes, and numerous other valuable variations. He conducted the Burbank Experimental Farms at Santa Rosa, California. On this farm as many as 6000 experiments were often under observation at one time.

being discovered every year; explorers are finding new and hitherto undescribed plants and insects, mosses and ferns, bacteria and molds. These are not newly formed species. They are only now being observed.

279. Animals and Plants of the Future.— We need expect no new species for a long time. We may make discoveries of species new to science in the woods, streams, and marshes of our own neighborhood; the interior of the continents of Africa, Asia, and South America probably

have many species of various forms not yet recorded; but the animals and plants of the future will be much like those of the immediate past.

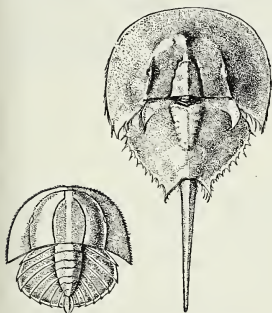


FIGURE 359. HORSESHOE CRABS

At the left is what is known as the "trilobite stage" in the development of the horseshoe crab. How did it get this name? (See Figure 354.) At the right is a full-grown crab.



FIGURE 358. FOSSIL LEAF OF DOGWOOD

This leaf fell into silt and sand that afterward hardened into rock and preserved its form and outline.

Animals and plants from generation to generation tend to vary, sometimes slightly, sometimes widely. This seems to be a characteristic of protoplasm. Man may observe these variations or mutations and preserve such as he desires by propagation. Variations or mutations may occur where man does not observe them, and these may be preserved by nature if they aid the species in survival or they may be lost if they retard or handicap the species in survival.

A crow may be hatched that bears white feathers. If a man observes this and rears the bird in a

bird nursery, the young may be a variation that will survive for a time. On the other hand, if the adult crows refuse to feed this unusual youngster, he may starve. His white coat would be a handicap.

A seedless orange would fail to perpetuate itself in nature but when man propagates the seedless orange, it becomes more abundant than those with seeds.

The future, then, of plants and animals may be predicted with some degree of certainty. We shall have, for example, larger hogs; hogs more resistant to disease. We shall have faster race horses; cows that give more and richer milk. We shall have earlier and brighter colored apples. So we might predict all along the line where the hand of man reaches to control his favorite fruits, flowers, and animals.

280. What about the Animal, Man? — Shall we have a super race of men? There is no indication of a super race if we mean by this a race of physical giants. Neither is there any indication of a race of intellectual giants. We may expect a longer average life as we learn more about health and disease. We may expect a happier life as we learn social controls. We may expect a richer life as we learn to eliminate all those factors which deny to anyone the full opportunities of an abundant life.

SUMMARY

The more we learn of living things the more willing we are to accept the idea that the earth is the common mother of all life. We also learn to accept the idea that the earth had a birth or origin in the materials of the sun. So the sun may be looked upon as the great mother of the earth and the other planets of the solar system. Again, the early plants and animals may be thought of as the forbears of those that come after them and which are living today.

When we apply the yardstick of time to the long series of events that have taken place since life began, we find need for a new conception of time measurement. We may use B.C. and A.D. in connection with events within the last few thousands of years but when we deal with millions of years we find that these letters give us little help towards arriving at the great span our millions of years measure.

Life started in the Pre-Cambrian period nearly two billions of years ago. As we examine the rocks laid down during all these years we find evidences of life in the form of fossils and other traces. By studying these evidences we are able to trace quite accurately the progress that life has made through the ages.

QUESTIONS

In what sense is the earth the mother of all living things? How may we explain the birth of the earth? Could the earth hold down an atmosphere when it was small? Give reasons for your answer. What is the name of the substance through which life manifests itself? During what period of time did all plant life live in the water? What forms of life characterize the divisions (eras) of the Paleozoic age? Name three ways in which fossils may be formed. Are all the species of animals and plants already named? May we expect a race of giants to appear among men? What hope of better conditions of living has man?

REFERENCES

Mary E. Boyle, *Prehistoric Man*, Little, Brown and Company
James, *The Beginnings of Man*, Doubleday, Doran
Lankester, *Extinct Animals*, Henry Holt and Company
Mather, *Old Mother Earth*, Harvard University Press
Osborn, *Men of the Old Stone Age*, Charles Scribner's Sons
M. E. Wells, *How the Present Came from the Past*, The Macmillan Company

omit
CHAPTER XXVII

HEREDITY AND VARIATION

*So careful of the type . . .
So careless of the single life.*

—TENNYSON

281. Introduction. — You have now completed a general study of plants and animals and the wide variety of places in which they live: in the ocean depths, on land, and in the air. In this survey of the living world, you became aware of the large number of different kinds of animals and plants and, in certain groups, of their incredible numbers. No matter how small or large, whether animal or plant, every living thing possesses structural resemblances to its parents. This similarity is so striking that when once we become familiar with the sparrow, the rose, the crayfish, or the pine tree, we expect to find the same combination of structures and the same habits of living in these organisms wherever they exist. You have just reviewed the life of the past and been astounded at the incredible length of time that certain animals have continued to resemble their parents. The little lingula (Figures 345 and 346) has gone on repeating itself for many millions of years, and the fossil forms are so similar to those existing today that there is no difficulty in recognizing them as being related.

282. Variation. — In our study of the grasshopper, the frog, and the flowering plants, as well as the microscopic unicellular organisms, we noted their method of reproducing new forms like themselves. The resemblances between parent and offspring are strikingly exact even as to details of behavior, yet they are never quite identical. In Figure 360 are shown three hands, and although they are normal hands, yet each has distinctive

features. The hands on either end are those of the parents, and the one in the middle is the daughter's. If you study carefully the details, you will note that the mother has a short little finger, about as short as the thumb. The same peculiarity is seen in the hand of the daughter. She is thus said to inherit the length of



FIGURE 360. HEREDITY IN HANDS

her little finger from her mother. This is called a *character*. In the study of heredity, then, it is obvious that this character, shortness of little finger, is inherited entirely from one parent and not as an intermediate between the length of little finger of the mother and the father.

The distance between the base of the thumb and the first finger in the father's hand is proportionately greater than the same distance in the hand of the mother. This peculiarity is evident in the hand of the daughter, who is but eleven years old. As she matures, this distance will become greater and she will exhibit a characteristic inherited from her father. There are a number of other peculiarities in the hand of this daughter that can be found in the hand of one or the other of her parents. This we call *variation*. A child differs from its parents, then, according to the number of characters which it receives from each.

This fact of variation extends throughout the entire range of animal and plant life. Figure 361 gives the range in the heads of



FIGURE 361. HEADS OF TIMOTHY HAY

timothy hay, and it is easy for you to realize the difference in the amount of seed that would be available either as food for animals or to produce more timothy hay. Often the seeds in the small heads are not supplied with sufficient nourishment to produce a seed-plant. Figure 362 shows the practical value of planting good seed that will yield a large crop. For each of the five bundles, the same measure of seed was planted in the same kind of soil. It is clearly unprofitable to use poor seed.

The several varieties of American grapes are descended from an original species. Many of these varieties have been in exist-



FIGURE 362. BUNDLES OF TIMOTHY HAY

These were all raised under the same conditions from equal amounts of seed.

ence since white men came to this country, and during this time they have acquired a strong resistance to certain parasitic dis-

eases which are very destructive to the European grapes. Among the diseases is one that is caused by a minute plant louse that lives in the leaf, stem, or root. This insect is known as *Phylloxera* (fil'ōk-sē'rā). In addition to this animal disease, there are three plant parasite diseases that attack grapes: black rot, downy mildew, and powdery mildew. Any of these four diseases is able to kill grape vines, and more than one may attack the same plant at the same time.

A few years ago these diseases became so widespread in Europe that they threatened to destroy most of the European vineyards. Many experiments were undertaken to save this valuable industry. It was discovered that the European grapevine could be grafted on to the root of any one of several of the

American grapes; and when these vines were thus grafted, they were found to possess a resistance to all four diseases, with the result that the vineyards of Europe were saved.

This success was due to scientific study, which discovered the difference between the European and American grapes in their power to resist disease and the fact that the quality of the European grape was not altered by grafting it onto the roots of the American varieties. Here we have an example of variation, not in the shape and size of the parts, but in their resistance to disease.

283. The Stuff of Heredity. — One generation of animals or plants passes to the next generation living material which is capable of building a new form. This process we call reproduc-



FIGURE 363. GALLS ON GRAPE LEAF
CAUSED BY PHYLLOXERA

The roots also are injured by this disease.

tion. Reproduction in plants and reproduction in animals is of the same general order. Before we start to examine the "stuff of heredity," we may quote three generally accepted statements.

1. All living things have started from parents.
2. All living things are made up of cells or units of construction. One-celled animals (protozoa) and one-celled plants (protophyta), of course, have but one cell.
3. Higher animals and plants reproduce by forming eggs and sperms, the fusion of which starts a new individual.

We have studied the cell (Figure 34) and noted its parts. The stuff of heredity is located in the *chromosomes* of the nucleus and is made up of *genes*.



FIGURE 364. STAGES IN CHROMATIN CHANGE

The chromatin in the nucleus passes through a series of stages each time a cell divides. A, growth of chromatin; B, formation of chromosomes; C, a single chromosome dividing lengthwise; D, condensation stage; E, the beginning of the migration of chromosomes; F, later stage of migration; G, a new nucleus is forming; H, the nucleus is completed.

284. What Are Genes? — No one has ever seen a gene. There is no reason to believe anyone will ever see one. Neither has anyone ever seen a molecule of oxygen; still, we know much about the behavior and properties of oxygen. Within the last few years, we have learned much about the location and behavior of genes.

During cell division, the chromatin material (the substance in the nucleus of cells) passes through a definite series of changes. The important steps in this series of changes are similar in all forms of life thus far studied. Chromatin increases greatly in amount and collects into a definite number of separate bodies to which the name "chromosome" is given.

The number of chromosomes in different plants and animals varies and is of secondary importance. During reproduction,

each chromosome undergoes a division process and the first step is a longitudinal splitting (Figure 365), which results in distributing the chromatin material equally to the two new cells. The genes are believed to be very minute particles of chromatin located in each chromosome, and arranged in a given order. When a chromosome splits into two parts, the theory is that the genes themselves also divide, and are thus distributed to each cell. The genes, then, grow and increase in number with each cell division.

285. Mendel and His Garden. — Gregor Johann Mendel had one of the greatest gardens that was ever cared for by man. This garden was not noted for its fine flowers or rare plants, for it contained many kinds of plants that were common to the vicinity. In this garden, peas received special attention. The peas were planted to solve a great question that had baffled the minds of the world's greatest scientists. Mendel proposed to find out the laws involved in heredity, at least in so far as peas could teach him.

He selected peas that grew long (tall) vines and those that grew short (dwarf) vines; those that blossomed in purple and those that were white; peas that were smooth and those that were wrinkled; peas that had yellow seed coats and those that had green seed coats. He bred them until he had produced pure strains. By means of artificial and controlled pollination, he took pollen grains from the various kinds and put them on the stigmas of other kinds, making a great variety of crosses. His records are exceptionally well kept. Finally in 1865, after many years of exacting work, he published a forty-page pamphlet in the proceedings of a scientific society, but the world was not awak-



FIGURE 365. A PROTOZOAN CELL

This cell is dividing, showing spindle and chromosomes. (Photograph by S. M. Hall.)

ened to the significance of his discoveries for more than thirty years.

In 1900 three botanists, De Vries in Holland, Correns in Germany, and Tschermak in Austria, carried on experiments which confirmed Mendel's findings. Soon such study was carried on in many countries and it has become very extensive and complicated. What Mendel's findings were may be set down as :

1. The law of dominant and recessive characters
2. The law of unit character, involving the gene
3. The law of segregation

Mendel found that tall peas and dwarf peas when crossed gave all tall peas in the first planting (generation). The crossing

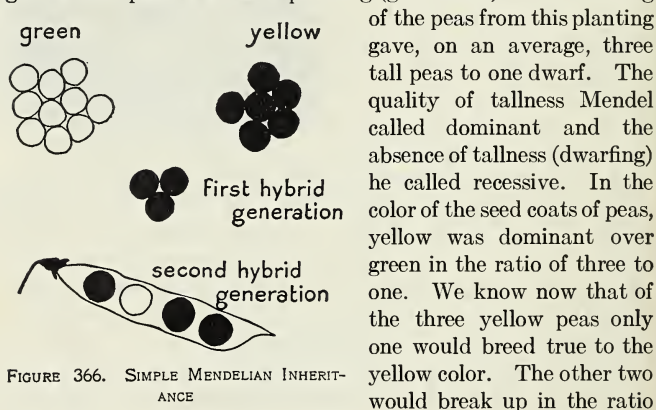
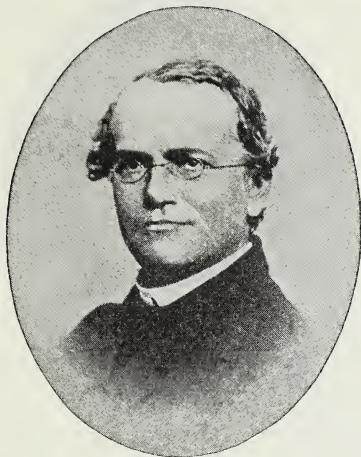


FIGURE 366. SIMPLE MENDELIAN INHERITANCE

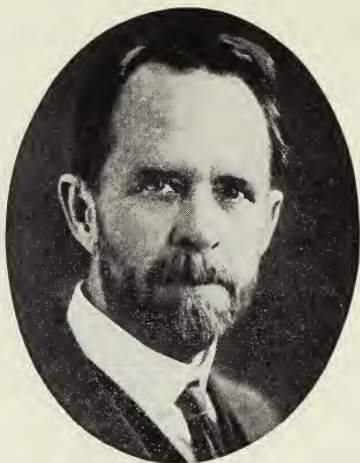
of the peas from this planting gave, on an average, three tall peas to one dwarf. The quality of tallness Mendel called dominant and the absence of tallness (dwarfing) he called recessive. In the color of the seed coats of peas, yellow was dominant over green in the ratio of three to one. We know now that of the three yellow peas only one would breed true to the yellow color. The other two would break up in the ratio of three to one, or if bred further, in the ratio of one to two to one (1-2-1). That is, there would be one pure yellow strain, two yellow that would not always breed yellow, and one pure green strain.

286. From Mendel to Morgan. — To study heredity there is need for rapid reproduction. There are three generations of man in a century; one of peas each year. That is rather slow work. Where may we find rapid reproduction, several generations a year? Dr. Thomas Hunt Morgan, in searching for such a form,



GREGOR JOHANN MENDEL (1822-1884) was born of peasant parents at Heinzendorf, a German colony in the center of the Slavic population of Austrian Silesia. He made his way through what we know as grammar school and high school, and the gymnasium, which is similar to our junior college, and finally graduated from the University of Zurich. During his university life he had an opportunity to study under a great botanist, Karl Wilhelm von Nägeli, so it is not strange that he knew how to work with plants.

After his college education was finished, he entered the priesthood. He occupied his leisure time by experimenting with plants in his garden. *His experiments, which continued for a number of years, were so carefully made that they could be verified by others.* The result was a great discovery revealing the manner in which the traits of parent pea plants are transmitted to their offspring. When the same method of study was applied to other plants and to animals, it was found that Mendel had really discovered how traits in all living things are transmitted from parents to their offspring.



THOMAS HUNT MORGAN was born in Lexington, Kentucky, in 1866, and for the past forty years has devoted his energies to teaching and research in biology. His versatile mind has delved into the theoretical and experimental phase of vital activities and his discussions of these subjects are to be found in many scientific journals and books.

The great universities have bestowed upon him their highest degrees, while foreign scientific societies have added his name to their long roll of honor. In addition to these high distinctions, Dr. Morgan was given the Nobel Prize in 1933, making him the first American biologist to receive this award.

During the past quarter of a century, Dr. Morgan has been devoting his research to the study of heredity and making a very thoroughgoing investigation of the fruit fly, *Drosophila melanogaster*. This small fly is very common and can easily be collected and studied as it feeds on various fruits. It is important to recognize that this small insect has been the means of contributing to a scientific analysis of heredity and that Dr. Morgan and his scientific associates have done more to advance our knowledge in this difficult field of research than his host of predecessors.

hit upon the fruit fly. This fly completes a generation in two weeks or less. This means that twenty-five generations could be observed in a year. Man would require eight hundred years for twenty-five generations. Since 1910 it has been possible to study more than five hundred generations of flies. It would require 15,000 years to study that number of generations of man.

Figure 367 shows seven fruit flies embedded in balsam to illustrate Mendel's laws. The upper right shows a fruit fly with normal wings; the upper left shows a fruit fly with vestigial wings.

The breeding of these two flies produces flies with normal wings like those of the lone fly in the center of the picture. This fly, bred with

another of like ancestry, will produce young that have normal wings in the proportion of three to one. The fourth will have vestigial wings. However, of the three with normal wings, only one will breed true and give young with normal wings. The other two will breed the same as the lone fly in the center of the picture; that is, three out of four of the young will have normal wings.

Since chromosomes, genes, and other features of protoplasm are alike throughout the organic world, we feel that what the fruit fly shows us is largely true also for man. The unappreciative world of Mendel's time may be compared to the alert and



FIGURE 367. FRUIT FLIES ARRANGED TO ILLUSTRATE MENDEL'S LAW

One of them has vestigial wings, another long wings. The crossing of these flies will produce young that all have long wings. When these are crossed with one another, they will raise young of which one out of four will have vestigial wings and the other three will have long wings.

intellectual world of Morgan's time. Morgan's work has been followed by the scientists of the world since he began it in 1910. Just recently he was awarded the Nobel prize for his outstanding discoveries in this field.

287. Mutation. — One of the first records of what we now call a *mutant* was termed a "sport." In 1791, a sheep farmer in Massachusetts named Seth Wright discovered that one of his male sheep had a long body and short, bowed legs. The story goes that he was having much trouble in keeping his long-legged sheep in his pasture and it occurred to him that he might use this "sport" to reduce the length of the legs of his flock of sheep. In the spring, he found that of the lambs sired by this short-legged sheep some were like the father and some like their mothers. Separating the short-legged lambs and continuing to breed them with short-legged lambs, he found that they produced only short-legged lambs; so in a few years, he was able to raise a flock of sheep that could not jump over fences.

We designate such a sport a mutant, because it is a new type and its differences are due to changes in the arrangement of the genes in the chromosomes.

Another form of the same kind of change is shown in a small water-flea (*Daphnia*) in the Experimental Laboratory for Evolution at Cold Spring Harbor, Long Island, where a strain of *Daphnia* has been bred for 363 generations. This strain of water-fleas does best when the temperature is about 20° C and dies when the temperature is above 26° C or below 11° C.

After fourteen years of observation, a new mutant appeared which thrived best at a temperature of 27° C and died when kept at 20° C. The only observable difference is the altered response to heat and cold. You can easily see how such a mutation would help in enabling the animal to spread to warmer regions.

Careful students of heredity are slowly collecting mutants in beans, tobacco, insects, and many other forms. Some of the changes are minute and do not attract attention. Up to the present, there is no scientific explanation for these abrupt changes, nor do we know just what alterations actually take place in the

chromosome. The importance of mutation in the production of permanent new forms of animals and plants is believed to be very great.

In breeding the fruit fly one finds that those with vestigial wings develop jumping habits that are wholly unlike normal

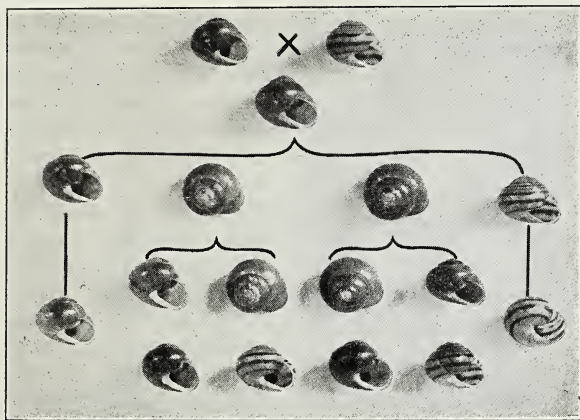


FIGURE 368. HEREDITY IN SNAILS

Notice how Mendel's law is illustrated when a snail having a solid-colored shell is crossed with one having a striped shell.

flies. They jump about in the breeding jars like small crickets. This is their regular behavior. Is this the result of heredity or environment? Is it an adaptation?

288. Improvement of Plants and Animals by Breeding. — In order to furnish the farmer with the necessary information upon all such subjects, scientific experts are devoting a great deal of time to experimentation. The following example shows the importance of such study in helping man to produce new and better kinds of plants and animals.

Figure 369 shows some bearded wheat, the pollen of which was placed on the stigma of the wheat flowers that formed on the non-

bearded wheat shown at the right. When the kernels of wheat in this head ripened, they were sown and a plant was produced which grew a longer head, having practically no beards (the middle head in Figure 369). Such a head of wheat yielded more kernels than either of the parent heads. Now if the scientific



FIGURE 369. HEREDITY IN WHEAT

expert can make this new wheat plant permanent, that is, make it produce seed that will always grow large heads, he has furnished the farmer with a better kind of wheat and has made a new discovery.

The hard red winter wheat from southern Asia was crossed with a strain known as the red fife by Professor Saunders, a Canadian cereal specialist, and a hybrid form of wheat was secured which he named the marquis. This strain was propagated under

his direction for eleven years and then distributed to the farmers. In 1919, 11,800,000 acres of marquis wheat were grown in the United States and the yield had become the second largest of the different kinds of wheat then grown.

The application of the principle of unit characters in heredity works out interestingly in sheep. The tendency of sheep to collect in flocks as they feed in the pasture on the open range is really a dominant character, which is inherited; but it is not true of all kinds of sheep. If the breeder wishes to get the most satisfactory results, he will select the breed known as fine-wool sheep which show this flocking instinct best. This becomes important in the cost of caring for sheep out on the open ranges. One man and a dog can look after several thousand sheep that tend to graze in compact flocks.

The cattle known as Guernseys which were originally developed on the island of Guernsey furnish another interesting illustration of breeding. When the United States cattle men sought to improve their stock, they imported registered Guernseys into the United States. Taking advantage of the principles of heredity, the American breeder entered into extensive experiments. Skilled men studied the application of our modern laws of heredity, until they were able to produce a finer animal than those in the native habitat of the island of Guernsey. The result is that today more registered Guernseys are shipped to South America from the United States of America than from the island of Guernsey.

289. Barley in Wisconsin.¹ — The problem of the agronomist (one dealing with the theory and practice of crop production) of 30 years ago was to determine from the useful farm crops those best adapted to the soil and climatic conditions. Accordingly, Professor R. A. Moore, the Wisconsin agronomist, collected barleys from all over the world, studied their adaptation to Wisconsin conditions, and from this array of material the common 6-rowed Manchurian types were found to be the best suited. On the two well-known types, the Oderbrucker and Manshury, Professor Moore carried on intensive selection for yield, stiffness of straw, high protein, and good malting. Finally two superior new lines of the Oderbrucker were produced, the Wisconsin Pedigree 5 and Pedigree 6. The popularity of these barleys spread until all the barley grown in the state was of such pedigree. In the malting industry it also was held as the standard of excellence. But the rough, barbed beard was uncomfortable to handle, and despite the fact that improved machinery reduced handling to a minimum, barley growing lagged. Many farmers, even though they appreciated its value as feed, would not grow it on account of the disagreeable beard.

The next problem of the Experiment Station agronomists was to build up a barley without the objectionable beards. The first effort was to get rid of the beards entirely. Professor B. D.

¹ From a manuscript by Professor B. D. Leith of the University of Wisconsin.

Leith of Wisconsin, who took charge of the barley breeding work in 1911, started to create new barleys by hybridization. The plan was to use the superior Oderbrucker as one parent and



FIGURE 370. SMOOTH AND ROUGH BARLEY

another barley having some more desirable feature concerning beards as the other parent. Accordingly, the hooded was tried, but the hybrid progenies had either hoods or rough beards, so that parent was ruled out. Another barley having no awns (appendages making up the beard) on $\frac{2}{3}$ of the kernels and short awns on $\frac{1}{3}$ was used, but no hybrids could be found approaching the Oderbrucker in yield or stiff-

ness of straw. Then a new black barley with smooth beards was brought to Wisconsin in 1917 from southeast Russia and crossed with the Oderbrucker.

The first hybrid generation was all black and all rough. This did not disturb the plant breeder, for these are the dominant characters and simply cover up other characters which will appear later. So when these black rough heads of the first generation were planted the next year the heads of that crop appeared approximately in the following ratio: 9 all black and rough; 3 black and smooth; 3 white and rough, and one white and smooth. The interesting thing in this connection is that the white and smooth will always breed true for white and smooth, while the other classes will have some that will not breed like their parents. But only color and smoothness have become fixed characters in this white, smooth line; many other characters of economic value are in these white smooth heads in a mixed state. There will be found long and short heads, stiff and weak straws, low yielders and high yielders, those resistant to disease

and those susceptible, and many other characters of lesser importance.

The rebuilding of a strain starts here. Desirable characters must be sorted out and combined with other desirable characters until a new strain is rebuilt of as many desirable characters from both parents as can be brought together. This takes judgment on the part of the plant breeder, as many of these characters are not clear cut or easily recognized; sometimes they are modified by other characters, or they may carry over for a year without appearing. The season also must be reckoned with, as some seasons bring certain characters into expression, while others will bring different ones. To illustrate, only a very hot, dry season brings out drouth resistance. Every variation that appeared valuable was selected out, planted by itself to see if it was real or only shamming. Selection went beyond the purely agronomic characters, and disease resistance was studied in coöperation with Drs. J. G. Dickson and R. G. Shands. After a very careful study of a large number of selections grown in rows, a well-built recombination of good qualities of both parents was found in one line which was given the pedigree number 37. In 1927, 10 years after the cross was made, it was sent out to a few county agents and farmers to test its adaptability. Reports of the crop were very favorable. This was just the beginning. Two years later another sister line to Pedigree 37, known as Pedigree 38, the "Wisconsin Barbless," was sent out for trial in the state and was found even superior to Pedigree 37. Results from the Madison station, the branch stations, and reports from county agents and farmers have now covered sufficient time so that a fair evaluation of the Wisconsin Barbless barley can be made.

In 1930, reported yields of Pedigree 38 from 67 farmers averaged 52.5 bushels per acre, several reporting over 60 bushels. In 1931, a season of severe drouth, the average yield of Pedigree 38 as reported by 35 farmers was 36 bushels per acre as compared with a reported yield of Oderbrucker of 26.7 bushels per acre from 22 farmers. In 1932, reported yields of Pedigree 38 from

22 farmers give an average of 57.4 bushels per acre. A few unusually high yields of 70 bushels or above are reported. On the test plots at the Wisconsin Experiment Station at Madison a five-year average yield of the Pedigree 38 is 47.7 bushels per acre while the Oderbrucker yield is 38.9 bushels per acre. Favorable reports on its adaptability and high yielding quality have



FIGURE 371. FIELD OF WISCONSIN PEDIGREE 38 BARLEY

come from farmers who have grown it in Ontario and Alberta, Canada; Illinois; Indiana; Iowa; and Pennsylvania. These reports suggest a wide range of adaptability.

290. Eugenics. — The facts that have been brought to us by geneticists (students of the laws pertaining to heredity) who have studied plants and the lower animals lead us to assume that the same laws apply to human heredity because all are forms of life.

It was Francis Galton of England who coined the word eugenics, but Chinese, Greek, and Roman history have many eugenic references. The following interesting quotation was written by Theognis of Megara about 590 B.C.

We seek, Cyrrus, for rams and asses and horses that are well-born, and every one wishes them to spring from good stock. But a nobleman does not mind marrying a baseborn woman of a baseborn house, if she bring him

much money. Nor does a woman decline to be the wife of a baseborn man who is rich, but desires a wealthy man instead of a man of good stock. For they honor money. A nobleman takes to wife a woman from a baseborn house, and a baseborn man a woman from a house of good stock. Wealth has made the race impure. So do not wonder, Poly-paides, that the race of our citizens is obscure, for nobleness with base-ness is commingled.

Eugenics is the study of the biological and social agencies which may improve or impair the physical and mental qualities of man. It is a grave mistake to identify eugenics with the various fads and fancies that are given publicity from time to time, such as a "plan for making supermen," "government-made marriage," etc. Man has known for a long time that he could improve his domestic animals and plants, and eugenics is an attempt to apply the same methods to human betterment.

The problem of immigration is complicated, but there is a distinct phase of it that is related to eugenics. What is the connection?

All careful students of heredity have become convinced that the physical characteristics of man can be traced to some of his immediate ancestors. Does the same conclusion follow when we examine our mental and moral traits? Most students of

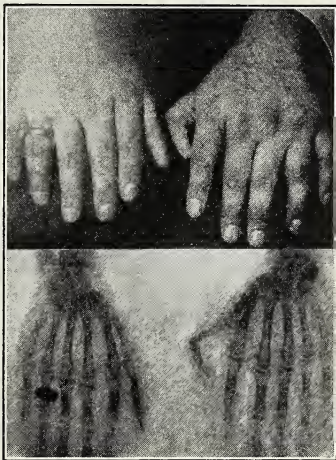


FIGURE 372. HEREDITY IN MAN

Physical characteristics are also hereditary. A doctor practising in the Caucasus region had a patient with six toes and six fingers. This man stated that, according to the pedigree in possession of his grandfather, this peculiarity had been transmitted in their family for about 700 years. It is an interesting coincidence that this man's name was Scipio, the same as Scipio the African, who lived over 200 years before our era and, according to history, had six fingers and six toes.

biology hold that the structure of the nervous system accounts in a large part for the way in which one thinks, and influences the results of the training which in part determines what we do. The specialist results from the training of special abilities. College and graduate training in some phase of biology is of little value to those who have no scientific ability.

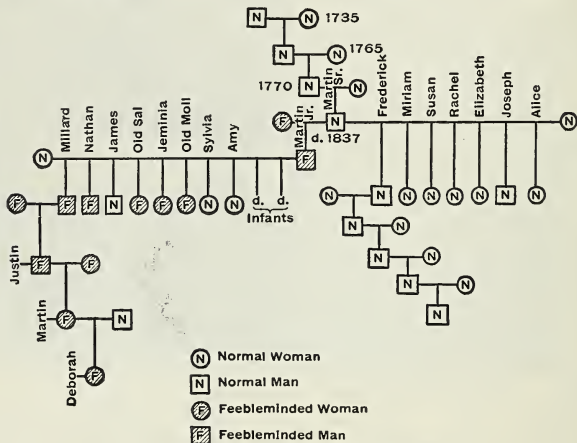


FIGURE 373. THE KALLIKAK FAMILY

Trace the ancestors on both sides through both mothers. Explain the differences. How many defective people do you find?

291. Study of Family Histories. — The histories of two notable defective families have been investigated, namely, the Jukes and Kallikak. The Jukes family history includes 709 descendants of Max Jukes, who was a shiftless backwoodsman. One half of the children died in infancy, and of those who lived, 310 were paupers and over 30 convicted criminals. The cost to the state in maintaining and prosecuting these criminals has been over \$3,000,000.

The Kallikak family shows in a striking fashion that mental deficiency when once started may persist for many generations.

Of 481 descendants traced from a feeble-minded mother, 143 were feeble-minded and 291 were inferior in intellectual ability. In this same family there are 496 descendants from an intelligent mother and only two show any indication of subnormal mentality, while the other 494 were successful citizens in their several communities.

In these two tragic illustrations, mental deficiency made a poor parent and there was a long line of poverty, misery, sin, and crime. In all of the great countries of the world, we find a long list of eminent men who are related by descent. In the Bach family there were 20 eminent musicians and over 40 less eminent. The Darwins became noted for their scientific ability two generations before the birth of Charles Darwin. Erasmus Darwin was an eminent man. He had a son Robert who was a distinguished physician. Robert was the father of Charles R. Darwin, who is regarded as one of the greatest men of science. The four sons of Charles Darwin all became prominent. Francis Galton, a cousin of Charles Darwin, was one of the most famous students of heredity.

In America we have the famous family of Edwards. Richard Edwards was first married to Elizabeth Tuttle, a woman of great mental power; from this union resulted one of the most brilliant families recorded. Jonathan Edwards, the grandson of Richard Edwards and Elizabeth Tuttle, was a noted New England clergyman. In 1900, 1394 descendants of Richard Edwards and Elizabeth Tuttle were known. Among these there were 295 college graduates, 13 college presidents and many school principals, 60 physicians, 100 clergymen, 75 officers in the army and navy, more than 100 lawyers, 30 judges, and 80 holders of public office. Richard Edwards' second marriage was to Mary Talcott, a woman of average ability; this union resulted in an average line of descendants.

The contrast between the Jukes and the Kallikak families on the one hand, and those of Bach, Darwin, and Edwards on the other, clearly indicate that good inheritance is the most priceless gift that ever can come from parent to child.

Thus general ability and a tendency to industry and thrift are qualities that can be inherited. The men and women who possess such mental traits carry on the business of the country and pay taxes, not only to support the government, but also to care for the idle, the shiftless, and the criminal. If we have inherited these traits of ability and industry, we should strive to keep them unimpaired and to strengthen them, so that we may pass them on to our children, in order that the next generation shall possess men and women who will be able to advance human progress beyond our best effort. If our inheritance is not good, we may do much by intelligent effort to overcome it.

292. Inheritance and Environment. — We cannot think of any living thing apart from its surroundings, and our common sense tells us that these surroundings have a large influence on the way organisms grow, mature, change, and adapt themselves to living in the air, on land, or in the water. The two factors, inheritance and environment, being interdependent, are both of great importance.

There are two points of view among those who are trying to relieve human suffering: (1) the social worker emphasizes environmental conditions, and (2) the eugenic worker stresses the hereditary history of the individual. The point of view of the social worker is evidently the one most commonly held, for in the past twenty-three years philanthropists have given away \$1,385,220,000 for the environmental improvement of the human race, while practically nothing has been given for improvement of heredity.

SUMMARY

Heredity and variation are two phases of biology which have attracted the interest of man ever since the early Greek naturalists reflected on the meaning of life. One of the early conceptions is in the familiar quotation: "I Jehovah, thy God, am a jealous God, visiting the iniquity of the fathers upon the children, and upon the third and fourth generation of them that hate me" (Deut. 10:9). This early morbid aspect of heredity has been replaced by the scientific approach to what we now understand to be one aspect of protoplasmic activity. The old adage that *like begets like* expresses

the general idea of heredity, but the modern study explains the manner in which differences as well as likenesses arise.

Heredity deals with the behavior of the chromatin during the reproductive events and centers its emphasis on the behavior of the genes. This method of study was first developed by Mendel and since his time has been greatly extended by a host of investigators. The application of the principle of dominance and segregation of genes has given the trained scientist the tools by means of which he remolds old forms of life and produces more valuable domestic animals and plants.

QUESTIONS

What is the meaning of variation? of heredity? Who began the scientific study of heredity? What was Galton's contribution? To what extent can man control the processes of heredity? How has the modern scientific study of heredity helped mankind? What does this study reveal to you about the value of having sound bodies and sound minds? Where do they come from?

TOPICS FOR FURTHER READING

1. Early explanations of heredity.
2. The difficulty of applying experimental methods to man.
3. How far can man modify animals and plants?

REFERENCES

- Altenburg, *How We Inherit*, Henry Holt and Company
 Castle, *Genetics and Eugenics*, Harvard University Press
 Conklin, *Heredity and Environment*, Princeton University Press
 Davenport, *Heredity in Relation to Eugenics*, Henry Holt and Company
 Guyer, *Being Well Born*, Bobbs-Merrill Company
 Jennings, *Prometheus*, E. P. Dutton and Company
 Lindsey, *Evolution and Genetics*, The Macmillan Company
 Morgan, *Physical Basis of Heredity*, J. B. Lippincott Company
 Smallwood, *Man, the Animal*, The Macmillan Company
 Walter, *Genetics*, The Macmillan Company
 Wiggam, *The Fruit of the Family Tree*, Bobbs-Merrill Company
 Wood, *Heredity in Royalty*, The Macmillan Company
- Journals
- Eugenics*. A Journal of Race Betterment
Journal of Heredity

Test III

I. Copy the words in column *B*, and opposite each write the number of the word or group of words in column *A* that is most closely related to it.

<i>A</i>	<i>B</i>
1. leaf	circulation
2. root hair	transpiration
3. chlorophyll	pollination
4. fibrovascular bundle	germination
5. stomata	fertilization
6. flower	protection
7. pistil	photosynthesis
8. bark	absorption
9. seed	nutrition
10. ovule	reproduction

II. Write your answers to the following on a separate sheet of paper :

1. Name six of the important functions common to all forms of life.
2. Describe how you can prove that one of these functions takes place in an animal or a plant.
3. Tell how your answer to 2 illustrates the experimental or scientific method.

III. Observe the following: a burning candle, a jar of germinating pea seeds, and a living frog.

1. What important process is going on all the time in the candle, the seeds, and the frog?
2. What two substances are required to carry on this process?
3. What two substances are given off as a result of this process?
4. How can you prove that this process is going on in the candle or the seeds or the frog?

IV. A boy buys some goldfish and places them in a jar of water. He forgets to feed the fish or to change the water, and the fish soon die.

1. Tell what might have been done so that it would not have been necessary to feed the fish or to change the water and yet keep them alive.
2. Mention four important products produced in an aquarium which has been so arranged that the fish will continue to live if they are not fed and the water is not changed.

3. Tell why each of these four products must be produced to keep the fish alive.

V. On a separate sheet of paper list the numbers of the *Applications* below. After each number, write the letter of the *Principle* that corresponds to that *Application*.

APPLICATIONS

1. Salt spilled on garden earth kills the plants in it.
2. Geranium leaves turn toward the light.
3. Germinating pea seeds turn lime water milky.
4. The roots of poplar trees often stop up drain pipes.
5. All flowers must contain either pistils or stamens or both.
6. Green plants will not thrive in a cellar.
7. Plants look thrifty after a heavy rain.
8. The temperature of the air in a bell jar containing a green plant is slightly higher than it is outside the jar.
9. Seeds do not need to be placed in the ground in any particular position to insure the downward growth of the roots.
10. Bacteria multiply by cell fission.

PRINCIPLES

- A. Plants absorb soil water by osmosis.
- B. Sunlight is necessary to green plants.
- C. Plant roots are influenced in their growth by gravity and water.
- D. Oxidation goes on in all living things.
- E. The stream of life is maintained in the world through the process of reproduction.

VI. Copy the one word in each of the following groups of related words that includes all the others in the group:

1. ameba, protozoan, microorganism, bacterium, paramecium
2. bat, whale, cow, mammal, woodchuck
3. grasshopper, fly, insect, locust, ant
4. frog, animal, fish, insect, man
5. root hair, protozoan, cell, white corpuscle, neuron
6. tree, carrot, aphid, rat, organism
7. sugar, starch, protein, vitamin, nutrient
8. formaldehyde, salt, iodine, antiseptic, mercurochrome
9. brain, tongue, organ, heart, liver
10. feeling, sight, taste, sensation, touch

VII. Copy the words or expressions in column *A*. Opposite each, write the number of the word or expression in column *B* that is most closely related to it.

<i>A</i>	<i>B</i>
storage place in the corn grain	1. chlorophyll
manufacture of food	2. medullary ray
liquid part of the blood	3. transpiration
passageway between pith and bark	4. lenticel
beneficial insect	5. spiracle
chemical change	6. cotyledon
pollen	7. endosperm
element	8. sperm cell
seed leaf	9. testa
opening in the bark	10. oxygen
	11. plasma
	12. dragon fly
	13. clothes moth
	14. digestion
	15. freezing of water

VIII. The statements below relate to cells. Copy the number of each statement and opposite it write the word or group of words which best completes its meaning.

1. ____ forms the living parts of a cell.
2. ____ is a denser central portion that governs the actions of the cell.
3. ____ are formed by groups of similar cells.
4. ____ is the name given to animals that consist of one cell.
5. ____ is the process by which cells obtain their food substances and oxygen.
6. ____ is the name applied to the smallest one-celled plants.
7. ____ is the type of reproduction usually found in one-celled plants and animals.
8. ____ is the process by which lifeless food is changed until it becomes a part of the living cell.
9. ____ is the elimination of waste from a cell.
10. ____ is the function of protoplasm that makes the individual respond to outside stimuli.

IX. Under *A* there are listed five conclusions of experiments. Under *B* are listed five statements related to the conclusions under *A* but arranged in different order. On a separate sheet of

paper, show the relation between each conclusion under *A* and its corresponding statement under *B*.

A

1. Green plants give off water through their leaves.
2. Starch is changed to grape sugar during germination.
3. Root hairs absorb dissolved minerals by osmosis.
4. Green plants absorb energy from the sun when they make starch.
5. The sap of a maple tree passes down through the bark.

B

1. Most seeds contain digestible nutrients but seldom digested foods.
2. Farmers are using an increased amount of commercial fertilizers.
3. Girdling a tree kills it in a short time.
4. Showers are frequent in the Adirondack Mountains during the summer time.
5. Corn grows most rapidly during the hottest months.

UNIT IV

THE BIOLOGY OF THE HUMAN BODY

CHAPTER XXVIII

AN INTRODUCTION TO HUMAN BIOLOGY

An honest man's the noblest work of God.

— POPE

293. What Is Human Biology? — We find that the only interest that the early races of man had in plants and animals was whether or not they could be used. Man had been using animals and plants for food for hundreds of thousands of years before he discovered that all were made up of similar cells and that all of the life processes take place in these cells. It is the cells and life processes, in their relation to man, that we shall now study, for these are what we mean by *human biology*.

The generalizations which you have learned about animals and plants make up the foundation for your study of human biology. However, since each species differs from every other one in some particulars, we must study man in detail to understand him biologically. Our tentative definition is: *Human biology is the particular application of biological principles to man*. We shall begin our study with a discussion of our knowledge of early man.

294. Thunderstones. — Superstitious men and women thought for a long time that certain peculiarly shaped stones which they found were endowed with some sacred power of protection. Some of these stones were chipped and so unlike ordinary stones that they were called thunderstones, suggesting that they had come from distant planets.

In 1690 a piece of chipped flint was found in England buried with the bones of an extinct mammoth. Fortunately this "thunderstone" was carefully preserved. But it was 169 years before this piece of flint was recognized as being similar to those found in France with bones of ancient mammals. It was deter-

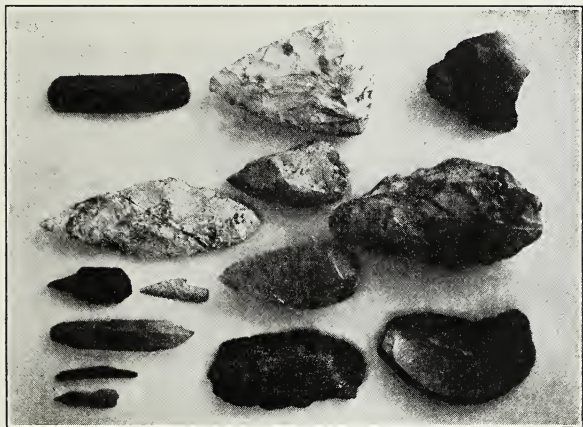


FIGURE 374. "THUNDERSTONES"

These stone implements represent the various phases of the old Stone Age in Western Europe.

mined finally that some of the alterations of the flint had been made by man and were very crude. If you study Indian arrowheads, you can see this same primitive art. Early man used a round hard stone to break the edges of the pieces of flint. Small piles of flint chips accumulated and remain as silent witness of these early efforts. After man learned that the chipped flints did not come from some distant planet but had been made by unknown men, they gave them the name of eoliths (*eos*, dawn; *lithos*, stone). The study of these eoliths tells us about the earliest work of ancient man and the remarkable skill he showed in forming arrowheads, spearheads, and knives with his crude instruments.

295. How Old Is Man? — In 1931 there was excavated in the Indus Valley of northern India a city that had been buried for several centuries. The people who occupied the houses 5000 years ago lived in buildings several stories high. Jewelry, toilet articles, artistic seals, weapons, tools, pottery, and small figures of men and beasts were found in great numbers. This

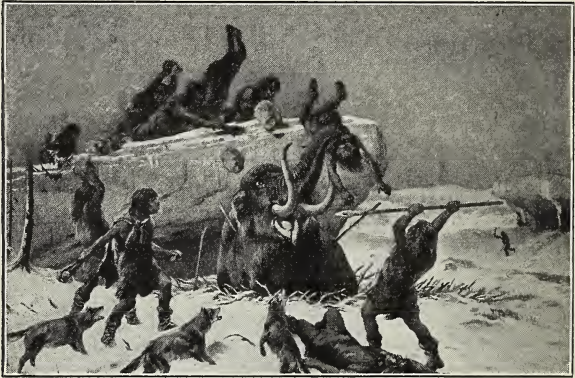


FIGURE 375. MEN OF THE STONE AGE
These men are shown killing an elephant.

discovery alone shows that man had learned at this early date how to construct buildings, live in organized cities, and carry on various activities. Long before this time, however, men were struggling to live and were seeking shelter in caves from the harsh climate and from unfriendly animals such as the cave bear, rhinoceros, wolf, and bison.

More recently, through discoveries in the field of physics, we have been enabled to judge time through radio-active changes. According to this system of estimating time, it has been determined that certain rocks existed about one and one half million years ago. Since we find the bones of man as well as chipped flints among these rocks, we can safely believe that man has existed for at least one and one half million years.

296. Prehistoric Man. — When geologists desire to express the time scale in a table, the older rocks are placed at the bottom and the younger at the top. The same plan is followed in arranging a table to show the age of plants, animals, and man. In the following plan, there is considerable difference of opinion as to the exact order in which these different races of man should be placed; and there is also a difference of opinion as to the number of years that marks the time of their existence. But the total number of unmistakable fossil remains of man is so large that there can be no longer any doubt about their having existed in prehistoric times.

The total information about early man, although lacking in completeness, is already very impressive.

The following table shows a possible origin for modern man:

NAME	DATE OF DISCOVERY	TIME OF EXISTENCE
Cro-Magnon	1868	Retreat of last glacier — 25,000 to 40,000 B.C. or more
Neanderthal	1856	Last glacial period before interglacial stage — 90-80,000 B.C.
Piltown	1911 and 1912	3rd-4th glacial period — 100,000 B.C.
Heidelberg	1907	After second glacier — 300-350,000 B.C.
Peking	1929 and 1930	Ice receding from the continent — 500,000 B.C.
Java	1891	Early ice age — 1,000,000 B.C.

297. The Java Man. — During the last part of the nineteenth century what many believe to be human fossils were found in Java. Only four fragments of the skeleton, a skullcap, two upper molars, and a femur were discovered. Such a discovery caused a great amount of excitement. Some thought the remains belonged to that of an ape, while others considered them an early form of man. After many carefully conducted measurements of the fragments, the consensus of opinion was that the skullcap and femur belonged to man. An ape having such a cranial capacity would have had a larger femur and would then have

been classed as a giant, while man has a comparatively large cranial cavity but a small femur.

It is possible to judge the height of the race of man only from the remains. It has been estimated that the Java man was about 5 feet 7 inches tall. Since no other remains were found with the Java man, it is supposed that his weapons were made of wood and had decayed and also that wood was used long before stone in making weapons.

298. The Peking Man. — In 1929 and 1930 remains of nearly a dozen human beings were found near Peking, China. The fossil fragments consisted of skulls and teeth. The Peking man was judged to have lived during the period when the ice was receding from the continent and the climate was warmer than when the Java man lived in the ice age. The civilization of the Peking man was more advanced, for among the remains were found quartz implements which were used in scraping skins and also charred bones which indicated that fire had been discovered. The use of fire, which was one of man's greatest discoveries, was essential to the advancement of culture.

299. The Heidelberg Man. — Twenty-two years before the discovery of the Peking Man, in the ancient river sand in Germany a lower human jaw was found. Teeth which were present in the jaw enabled scientists to diagnose the prehistoric remains as belonging to the human race. The present opinion is that the Heidelberg man, as this specimen is called, belongs to the first human race to live in Western Europe. No implements were found in this region, but other remains show that the Heidelberg man lived in a country inhabited by the bear, deer, and moose. In the meadows browsed the giant elephants with straight tusks. This indicates a forested country and a moist climate, the conditions in the period after the second great glacier.

300. The Piltdown Man. — At Piltdown, England, in 1911 and 1912 bones of a human skull were discovered in a rain-washed pit; in 1913 a tooth and nasal bones were found in the same vicinity. The Piltdown man lived in a fairly warm climate

between the third and the fourth glacial periods. A sharp-pointed stone (borer) which was probably used as a weapon and a curved scraper for scraping the hides of prey were two of the types of primitive instruments found.

301. The Neanderthal Man. — In 1856 skeletal remains were found in a valley in Germany which was called Neanderthal. In 1908 a complete skeleton was excavated at LeMoustier, France. Other skeletons of the same character have been found in Asia and Africa. The Neanderthal man, who lived during the last glacial period, lived in caves. For warmth and protection from the weather, he hunted bears which were used for food and clothing. He also used fire, evidence of which has been found in the caves. Buried with the remains we find stone-scrappers and spear-shaped points, a fact which leads us to believe that the Neanderthal man believed in life after death.

302. The Cro-Magnon Man. — In 1868, skeletons of the Cro-Magnon man were discovered in the Dordogne Valley in France. He lived during the ice age. From the implements which were found with the skeletons, it is evident that a great deal of care was taken in the burial of the dead. They also probably believed in an after-life. Cro-Magnon men have made a great contribution to students of prehistoric life, for they were skilled artists and have left a record of their observations carved upon the walls of caves in France and Spain.

Some believe that the Eskimos are descendants of the Cro-Magnon man; others think that the race died out; still others believe that Cro-Magnon blood is found in some modern Europeans.



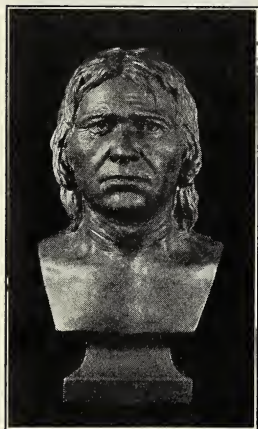
*American Museum of
Natural History*

FIGURE 376. NEANDERTHAL
MAN

This is a front view of the restoration by Dr. J. H. McGregor.

303. Home of Ancient Man. — Man's earliest home was probably the shelter of trees and an overhanging cliff. Such rude dwellings were supplemented occasionally by branches that kept out some of the wind and rain, and this gradually led to the weaving of the branches and placing them in several layers,

making a thatched roof. The famous cliff dwellers represent another class of human beings who have adapted themselves to living in excavations in the face of cliffs, and this habit still persists in various parts of the world. The Eskimo living in his ice hut represents another one of the crude, simple forms of protection. A great change in climate since man first appeared has been one of the important forces in causing him to adopt some form of protective shelter.



*American Museum of
Natural History*

FIGURE 377. CRO-MAGNON MAN

This front view is from the restoration by Dr. J. H. McGregor.

304. Man — an Animal. — We have just seen that man lives for a certain time and dies. During his lifetime he requires food in order to live and he uses this food in a manner similar to other animals. His lungs take in oxygen and give off waste carbon dioxide. Energy is required

for growth, for keeping the body at a constant temperature, and for locomotion. His brain and nervous system are like those of many other animals. The main difference is in the greater amount of brain material.

305. How Is Man Classified? — Scientists have regarded man as an animal for a great many years, but it was not until about 1750 that he was given a permanent name and placed in the animal kingdom. All animals with an internal vertebral skeleton are grouped as *Vertebrates*. This large group of animals is again subdivided into fishes, amphibians, reptiles, birds, and mammals.



FIGURE 378. AISLES OF UNHEWN STONE AT CARNAC, FRANCE
These were erected by prehistoric men.



Ewing Galloway

FIGURE 379. A THATCHED-ROOF COTTAGE IN ENGLAND



FIGURE 380. CLIFF DWELLINGS IN FRANCE

er. Nearly all of the members are adapted to arboreal life. The thumb and great toe can be more or less placed opposite the other fingers or toes. We find in the Primates flat finger nails and toe nails, which are very different from the claws of the dog or cat. A complete bony rim surrounds the eye, and the shoulder bones are well developed. These and other technical features clearly define the Primates. It is not an easy task, even for those who are experts, to classify correctly the nearly 600 different Primates. There are various terms in common usage for the higher Primates such as *ape*, *baboon*, *gibbon*, *orang-outang*, *chimpanzee*, and *gorilla*. The term *monkey* does not de-

Whenever a scientist finds an animal whose body is partly or wholly covered with hair and which supplies milk for its young in glands located on the ventral region of the body, he agrees to place the animal in the class of mammals. There are some nine orders of mammals, the last or highest being the *Primates*, the one to which man belongs. (See page 189.)

No less than 593 different species of recent Primates are known and almost every year new fossil species are discov-

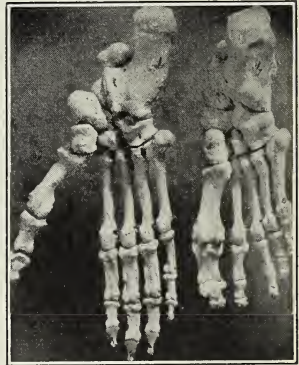


FIGURE 381. FOOT OF GORILLA AND OF MAN

Notice the similarity of the bones.

scribe any definite animal though it is often used in speaking of the smaller Primates.

In all schemes of classification, man is placed in a separate family distinct from the apes, gorilla, and others. The name of this family is *Hominidæ*, and we have only one living species in the world called *Homo sapiens*. The marvelous discoveries of fossil men which you have just studied reveal that some of



FIGURE 382. CAVE MEN PAINTING ON THE WALLS OF A CAVE

the earlier men were so different from modern men in bodily proportions that scientists describe them as belonging to other species.

306. Man's Power of Adaptation. — Man somehow learned to make fire and to use it. This great discovery initiated him into a new world. He could now remain in the cold cave when winter came. Our early records indicate that man was using fire before the close of the glacial period. Thus man began to live under artificial conditions and he entered a period of what has been described as domestication, and there began a series of adaptations that have continued until today. The use of fire, implements, and words places man in a separate class from the other animals. We must keep in mind his biological activities which are similar to the higher animals, but we cannot study the biology of man apart from the influence of his cultural life.



FIGURE 383. CAVE DRAWINGS

The top row shows bison, mammoths, reindeer, and horses from a cave in Dordogne, France. Some of the other drawings are from caves in Spain. Can you tell what animals are depicted?

STUDENT REPORT

The following table points out some of the common adaptations in animals. How are they related to the animal's success in life? Name some other habits which help to protect animals. Copy the form and fill it in. Do not mark your book.

ANIMAL	ACTIVE IN SUMMER	ACTIVE IN WINTER	HOME				PROTECTION			
			Earth	Water	Air	Nest	Night Feeding	Day Feeding	Color	External Skeleton
Earthworm										
Fly										
House Sparrow										
Dog										
Man										
etc.										

As men grew more numerous, they had to go farther afield for their necessary food. The same forces that compelled early man to migrate have continued to impel later man to move out into unknown regions to try to make a living more easily. We shall see how this has come to have a vital influence upon our own lives as we examine man's life processes more fully.

We have lived so long in heated houses that we think we could not get along without a fire, yet whole sections of Europe during the war had no heat, and our American soldiers were able to adjust themselves to what seemed to most of us an almost impossible change. This teaches us two important lessons: first, it shows something of how early man lived; and second, it shows the wide range of adaptation in the body of modern, civilized man.

We are now able to realize how man can live in all parts of the earth. When we discussed the places where frogs, fish, and grasshoppers were to be found, certain limits had to be mentioned.

This is not so with man. He possesses what no other animal has — the power to rise above the limitations of his environment. This he does by building a house of snow in the northlands and spreading a tent in Arabia. Man's constructive ability has led him to invent various devices for his protection such as stone, brick, wood, or concrete houses, something that no animals are



FIGURE 384. BUILDING A HOUSE OF SNOW

This picture was taken on one of Vilhjalmur Stefansson's trips to the North.

able to do. The reason why man is able to do many more things than animals is that he has a better mind, a mind that can adapt itself to many kinds of work, such as that done by carpenters, engineers, lawyers, teachers, and surgeons.

Scientists give four reasons in explaining why certain animals and plants are not adapted to living in all parts of the world: (1) lack of suitable food; (2) failure to adapt their lives to the peculiarities of climate; (3) too many enemies; (4) inability to raise their young. All these man has been able to overcome.

307. Environment Most Favorable to Man. — While man is found living in all parts of the world from the arctic to the equator, it is discovered that he is not equally energetic everywhere. Modern studies on the significance of temperature and

humidity in man's activities indicate that there are rather narrow limits within which he is at his best physically and mentally. The most comfortable temperature for white people is about 66°F .

Though men live in regions that are considerably colder or hotter than this, their activities are restricted. The extra vitality of the men who live in the temperate belt of the world permits a higher standard of living and yet leaves additional



FIGURE 385. A PRIMITIVE HOUSE IN JAMAICA

How is this house constructed? Notice the tropical growth around it.

energy for new experiments in all aspects of human activity. The mere fact that men have had time and energy for such experiments has given to us the furnace-heated house, lighted by electricity, in which we sit and listen to distant concerts over the radio. Test out this proposition and see if you can find whether or not we are using or enjoying any considerable number of inventions that were discovered by men living in regions that are extreme in temperature or where there is a marked absence of moisture in the air.

308. Human Welfare. — We are constantly changing from day to day, month to month, and year to year as long as we live. During these changes our relationship to our environment is a problem that we are constantly solving.

Biology can help us to understand many of the changes that we all have to meet between birth and death, the changes within ourselves and the changes caused by modifications in our environment. While it would be idle to assert that each of us can anticipate what is to happen in our life, it is possible to understand the events that are natural to the life of every one. When we can do this, we are able to adjust ourselves.

In the earlier sections of this book, you learned something of the plan on which all living creatures are built, the laws and rules which govern their method of living, growing, multiplying, and dying. From this study you should have gained first, a broad perspective of the fundamental biological processes in your own body; secondly, a knowledge of the intimate way in which animals and plants contribute to the happiness of man; and thirdly, how this knowledge may contribute to human welfare. In this section of the course in biology, we shall make man our major interest; this is the reason why we have termed it Human Biology.

This effort to understand what is happening in our bodies during our life has a fundamental purpose in it. We should be able to do the tasks which come to us as well as possible and if we are to do that, we must have healthy bodies and acquire good habits of living. Sooner or later every one of you must face the question of how you will make your life count for the most and to what extent the duties and responsibilities which come to you will enable you to live up to the highest standard of civilization. You will necessarily have to decide what your relations are to other human beings, since one of the finest things about living is your chance to serve others. This opportunity is greatest in mature life and there are many avenues of service that will be open to you, but you will never be able to carry these out satisfactorily unless you first understand your own Human Biology.

309. The Body of Man. — As we turn our attention to the working of the several organs in our own bodies, we shall find that many of the facts which we have learned in the sections dealing with biology are of great help to us. If we are to live free from pain, the organs in our bodies must work in a natural manner. If we are to work most efficiently, we must recognize that our organs need proper care. They can be made to do too much work as well as permitted to do too little.

We live in a variety of social groups and must learn to make adjustments. Each person has some features peculiar to himself to take into consideration. As we try to understand this matter of adjustment, we should keep in mind our physical inheritance and the equipment which nature has given us. Man can communicate his ideas and leave a record of his experience, through his invention of language. Our forefathers who settled this country gradually gained a mastery over the several phases of their environment. In the numerous adjustments which they had to make, they were handicapped more than you are, for there were no railroads, telephones, radios, or airplanes, yet they pushed their settlements from the Atlantic to the Pacific. Your task is to make your adjustments in the social environment in which you live. One of the first steps for you to take is to have an intelligent understanding of how your own body behaves. In the following chapters, we shall take up (a) The Covering of the Body, (b) Work and Protection, (c) Transportation, (d) Supply and Demand, (e) The Regulating Mechanisms, (f) The Beginning and the End.

SUMMARY

Human biology introduces you to the study of the most interesting animal that has ever existed. He has the same life processes as all animals. (Name them.) The earliest discoveries of man were chipped flints. Man has been living on our earth for possibly one and one-half million years. Our oldest record of man's observations of animals is his drawing of wild horses, deer, bison, and other animals on the walls of caves.

Modern scientists have attempted to restore these ancient men and even to tell us how and where they lived.

Man does not live so long as some animals. He is classified as an animal in the Primate order and placed in a separate division. There is but one existing species of man, *Homo sapiens*. The discovery of fire, of implements, and of the use of words place man in a separate class from all other animals and thus enable him to live in all climates and to leave a record of his activities. Men living in the temperate regions have contributed most to our modern civilization.

SPECIAL TOPICS FOR DISCUSSION

1. To what extent does civilized man control his environment?
2. To what extent do animals other than man control their environment?
3. To what extent is man's efficiency controlled by his environment?
4. Do animals show originality?
5. Contrast the life of ancient man with that of civilized man. Which one had the more freedom? Which one was the more efficient? The life of the American Indian is a good type to look up.
6. How long does man live? Do animals live longer? Which ones? What animals live the shortest time?
7. How do the early homes of man compare with the homes of some of the higher animals like the bears, bats, or muskrats?
8. Early man migrated from place to place. Do animals migrate? What are some of the reasons? Do these reasons apply to the migrations of man?

REFERENCES

- Curlis, *Science and Human Affairs*, Harcourt Brace and Company
 Dorsey, *Nature of Man*, Harper and Brothers
 Heard, *The Emergence of Man*, Harcourt Brace and Company
 Hornaday, *Minds and Manners of Wild Animals*, Charles Scribner's Sons
 Judd, *The Psychology of Social Institutions*, The Macmillan Company
 Kellogg, *Animals and Man*, Bobbs Merrill Company
 Mather, *Sons of the Earth*, W. W. Norton and Company
 Osborn, *Men of the Old Stone Age*, Charles Scribner's Sons
 Smallwood, *Man, the Animal*, The Macmillan Company
 Smith, Elliott, *Human History*, W. W. Norton and Company
 Sollas, *Ancient Hunters and Their Modern Representatives*, The Macmillan Company
 Van Loon, *Ancient Man*, Boni and Liveright
 Wilder, *Pedigree of the Human Race*, Henry Holt and Company

CHAPTER XXIX

THE COVERING OF THE BODY

*Know then thyself, presume not God to scan;
The proper study of mankind is man.*

— POPE

310. Which Animals Have a Skin? — If you will review what you have learned about animals, you will find that there is really no such thing as a mass of living protoplasm that does not have some form of protective covering. Even the outer layer of an ameba is now regarded as acting in this capacity. A paramecium has a thin cuticle which covers the entire animal and through which the cilia protrude. The starfish and crayfish have both a skin and an external skeleton. The skins of invertebrates vary greatly; but all vertebrates have a skin that is built on the same general plan. We need to know the parts before we can explain how the skin works.

311. Parts of Our Skin. — There are two main parts, the outer layer called the *epidermis*, and the deeper layer, the *corium*. (See Figures 386 and 387.)

The epidermis is made up of several layers of cells. Those on the outer surface are dead and are constantly being shed. Dandruff in the hair is an example of dead epidermal cells. You may have seen the shed skin of a snake, which is an illustration of an animal that casts the outer skin in one piece. Beneath the dead and dying cells of the epidermis is found a layer containing many spaces which are filled with a fluid. This layer, the *mucous* layer (Figure 386), makes up a strong, spongy membrane that protects the deepest layer of the epidermis. The innermost layer is continually undergoing cell division in order that new cells may take the place of those that are dying.

All injuries to the epidermis are repaired through the active growth of the germinal layer of the epidermis.

On the inner surface the epidermis is in direct contact with the second layer of the skin, the corium. The corium differs in a

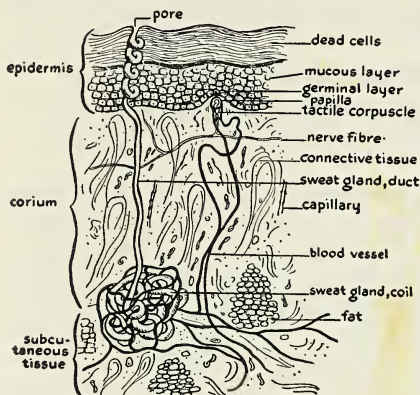


FIGURE 386. DIAGRAM OF THE SKIN

marked fashion from the outer layer as it consists of many interwoven bundles of strong connective tissue. Blood vessels, nerves, and fat masses are variously distributed in it. The boundary line between the epidermis and corium is thrown into numerous finger-like projections (*papillæ*). These projections are tallest and most

numerous in the palms of our hands and on the soles of our feet. In the skin of the face the *papillæ* are poorly developed and in old age may wholly disappear. Try to move the skin on the palm of your hand, then on your face, and you will have one explanation of their use. In some regions there are about 65,000 of these *papillæ* in a square inch!

312. Sweat Glands. — In Figure 386 is shown a long, slender tube opening on the surface of the skin and ending deep in the corium in a closely coiled mass. Into this coiled part, blood vessels penetrate so as to be in close contact with the cells of the sweat gland. These sweat glands are very numerous; there have been estimated to be more than one million of them in the skin of the average man. They are distributed over practically the entire surface of the body and are most numerous in the palm of the hand and sole of the foot.

The sweat glands take water from the blood stream and discharge it on the outer surface of the skin, where it evaporates. In this process of evaporation, the body uses up heat, thus providing a means for prompt cooling of the body when it is too warm. As much as a quart of water may be given off in a day by a man who sweats freely. There are also some wastes in this water, so that we have in this process of sweating one of the methods of excretion.

The heat in our bodies may be modified in still another way by changes in the blood vessels. When the skin capillaries are enlarged, the amount of blood

exposed to the cooling action of the surrounding air is increased. The skin appears red and often remains so until we have cooled off. Blushing is due to the same cause, — the sending of an extra amount of blood to the skin. When we are cold, these same skin capillaries contract and the skin looks pale or even bluish, due to the lack of the usual amount of red blood.

Man can stay in a dry, heated room at a temperature much higher than can be endured in a room where there is considerable moisture. This is due to the fact that the evaporation of sweat in the dry, heated room is more rapid than in the moist room.

313. Hair. — In Figure 387 is shown the relation of hair to the other parts of the skin. The outer end of each hair is dead but the root is alive and is nourished by blood vessels. Man is unlike all other mammals, for he lacks feeling, or tactile, hairs; and he differs from the higher apes, such as the chimpanzee or

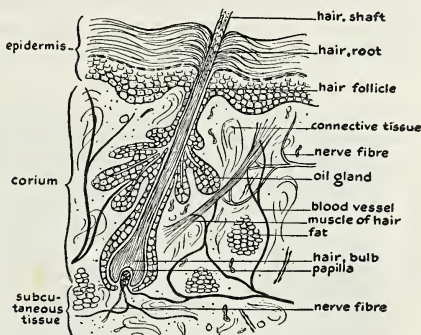


FIGURE 387. DIAGRAM SHOWING RELATION OF HAIR TO THE SKIN

gorilla, in the total absence of hair on the last joints of his fingers and toes. Man likewise has much less hair on his body than do any of the hairy animals. The average number of hairs per square inch in the scalp of adult man is 312, though it may run as high as 400. There is a wide variation in the number of hairs in the various monkeys.¹ Whales and elephants have lost their body hair but still retain some long hairs around the mouth termed "feelers."

You have learned that all birds and mammals are placed in the group of animals termed "warm-blooded" because their temperature is fairly constant winter and summer. You also know that both of these groups of animals have special skin covering, feathers and hairs, and that these structures assist in modifying the temperature of the bird or mammal. In very cold weather, the fur or hair of an animal stands on end and a bird ruffles up its feathers in order to increase the thickness of the air jacket. We have to rely on our hats and clothes to do

what nature has enabled some animals to do without any such help.

The hair is in part a distinguishing characteristic between the different races of men. Mongolians have straight, coarse, black hair, while the Negroes have short, wiry, closely-curved hair. Figure 388 shows the difference in a cross section between the straight and kinky hair. You

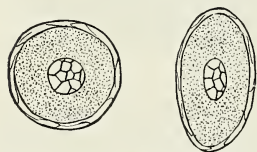


FIGURE 388. CROSS SECTION OF
HAIR

Which is the cross section of
straight hair?

should note that those who have naturally curly hair have a biological basis for it, and no amount of artificial treatment will give a permanent natural curl to the hair that is round when seen in section.

The rate at which hair grows varies somewhat, but if it grew but one millimeter (.03937 inch) in 24 hours, the body would need to manufacture some 10,000 hair cells in each hair.

¹ Schultze, "Man as a Primate," *Scientific Monthly*, November, 1931.

The color of the hair, like the color in the skin, is due to the presence of pigment. Man and animals derive this pigment, consisting of brownish or reddish granules, through inheritance, and their surroundings do not cause any marked change. Hair pigment tends to be light in children's hair, grow darker in that of middle age, and become gray, or disappear, in that of old age. Cutting the hair does not make it grow faster or change its character. The various agents advertised, as well as exposure to the sun, have little or no effect on hair growth.



FIGURE 389. THREE RACES OF PEOPLE

Notice the wide variation in skin and hair color.

314. Skin Color. — One cannot help being struck by the great variety in skin color. The fair, almost pigmentless skin of Swedish people contrasts sharply with the ebony-like blackness of the aborigines of parts of Africa and Australia. Between these two extremes are all gradations. The pigments that are found in the skin of the various races of man occur also in the animals. You have but to recall the beautiful colors of insects or of many of the vertebrates to realize the wide variety of pigments. The several shades of color in our skin are due especially to the proportionate amounts of a yellow pigment, abundant in the yellow races of Eastern Asia, and a black pigment, abundant in negroes. The number of pigment granules in the cells is the main cause for a light or dark complexion rather than a wide variety of pigments.

315. Nails. — The nails on our fingers and toes are flat but otherwise similar to the claws on our pet dog or cat. They are modifications of the outer layer of the epidermis. The nails are held in place by the papillæ, which are arranged in rows, and by the curvature of the nail. Our finger nails require about 250 days to grow one inch in length while those on our toes need nearly three times as long.

316. Some Skin Diseases. — During the winter we frequently have chapped hands due to excessive dryness. This is usually caused by the failure of the oil glands in the skin to keep the skin protected. If one has to use soap and water a great deal, chapping can be prevented by replacing the natural oil by rubbing the hands with glycerine, cold cream, vaseline, or olive oil.

Warts are local excessive growths of the outer layer of the epidermis. Almost any form of irritation may serve to start this growth. It is unwise and useless to cut them off as we do our finger nails. When warts occur on the soles of our feet, they are very painful and require the attention of a physician.

Moles, pimples, and boils are some of the additional skin disorders that require intelligent treatment. A mole that is left undisturbed is usually harmless as the mass of pigment cells will remain inactive; but when irritated by a collar or belt, the mole may take on an active stage of growth that frequently leads to serious consequences as it scatters to other parts of the body.

During adolescence the skin shows excessive oiliness and the oil gland openings become plugged up with dirt, causing black-heads. Pimples occur not only on the face but also in the skin of the shoulders and chest. This is a difficult trouble to cure. The best remedy is to keep the skin clean and watch the diet, since many of the worst cases show too high a sugar content in the blood.

Many boils are due to infections in spaces around the hairs. The bacteria come from without and not from bad blood. In addition to these modifications in the skin, parasitic fungi cause

ringworm, and the itch-mite and lice occasionally live on the hair and on the body. Lice feed on the blood received from bitten man and they are the chief carriers of typhus fever. Had Napoleon known this fact, it might not have been necessary for him to retreat from Moscow. During the World War extensive measures were devised to keep the soldiers free from lice.



© Harris and Ewing

FIGURE 390. FINGER PRINT DIVISION OF DEPARTMENT OF JUSTICE
Here the world's largest collection of finger prints has been assembled.

317. Finger Prints. — If you press your thumb on an ink pad and then place the inked thumb on a paper, you will leave a pattern of ridges that exist in just this shape in no one else. These ridges are due to the form which the papillæ take. One of the spider monkeys that uses its tail to hang onto limbs of trees has similar ridges in the hairless skin covering that part of the tail. Finger prints constitute a valuable method of identifying human beings and some states have laws requiring finger prints to be taken of all criminals.

318. Skin, an Index of Health. — When we look at one another, it is the skin that we see on the face and hands. We judge that the person we are looking at is sick or well by the

appearance of the skin. No amount of face decoration can conceal what lies beneath it. The appearance of good health does not come in packages. The skin itself is kept healthy only through the proper working of the body.

Our modern conception of health always involves bathing, not only to remove dirt but also because of the stimulating effect upon the nervous system.

SUMMARY

The skin of all vertebrates consists of two layers, the outer, the epidermis, and the inner, the corium. The free surface of the epidermis of man is constantly dying and being replaced. Hairs and nails are formed from the growing layer of the epidermis. We are born with a given color in our hair and skin and no amount of treatment will bring about a permanent change. It is the skin that we really see when we look at our friends and say, "How well you are looking." If we can keep our bodies in good health, our skin will go a long way to make us look as well as possible.

QUESTIONS

Which animals have a skin? What are the parts of the skin of vertebrates? Which structures are found in the skin of fishes and birds that are lacking in that of man? How does the skin of the frog differ from ours? What are sweat glands? their use? Compare the hair of man with other mammals. Make a list of the ways in which the skin affords protection to our bodies.

SPECIAL TOPICS FOR DISCUSSION

Do the inhabitants of the tropics have more sweat glands than those living in temperate regions? What do we know about baldness? How important are finger prints in identifying any one? What do you think about the use of cosmetics?

REFERENCES

See list of books, page 505.

CHAPTER XXX

WORK AND PROTECTION

*Man is all symmetrie,
Full of proportions, one limbe to another.*

—HERBERT

319. Introduction. — Movement is the first fact that we study about living animals. The movements of breathing and the beat-

ing of the heart sustain our lives, and spoken words reveal to us the stranger or friend. But neither stranger nor friend would be recognized were it not for the fact that our bodies keep a constant shape due mainly to the number and arrangement of the bones of the skeleton. The word *skeleton* meant to the Greeks a dried-up body, but to us the term is restricted to bones, cartilage, and ligaments. The bones are the most durable part. The

skeleton furnishes a place for the attachment of muscles and also protects the brain and other delicate organs.

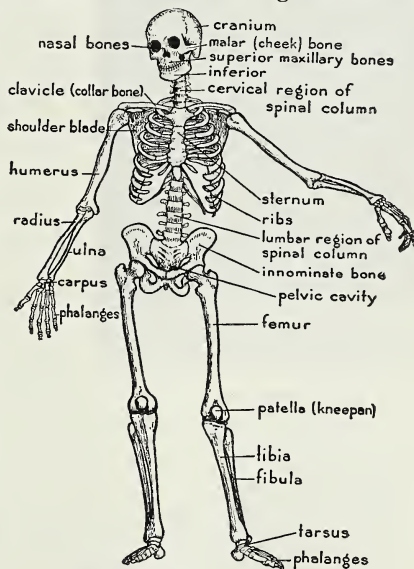


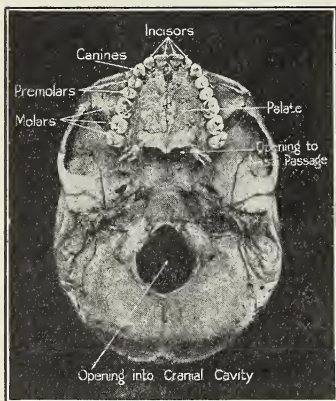
FIGURE 391. SKELETON OF MAN

Immediately beneath the skin of higher animals and man is found a curious tissue that exists nowhere else. This tissue makes up the main parts of the muscles. A great deal of study has been given to the movement in muscles, but there is no clear idea of how the results are produced. We do know that the movement of muscles is not like the movement of plants or of various kinds of engines. Our muscles do all of their work by pulling; they are able to contract lengthwise and thus bring their two ends nearer together.

We naturally think of the muscles as working when we are running or walking, but every position that our bodies take utilizes many muscles. In standing erect or sitting up straight we use many muscles, and in using muscles, heat is formed.

Muscles exist in every part of the body where movement is needed for the life processes, as in the walls of the heart and blood vessels and in the walls of the digestive canal.

The muscles that form the



Henry W. Stiles

FIGURE 392. SKULL SEEN FROM BELOW,
WITH LOWER JAW REMOVED

main part of the body and are popularly spoken of as flesh make up from forty to fifty per cent of our total weight. These are the muscles that have one or both ends attached to the bones of the skeleton.

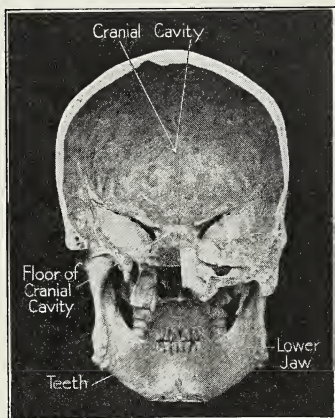
320. Body Regions. — The body of man, like that of all of the mammals, is divided into head, trunk, and limbs (Figure 391). These are the *regions* of the body. The trunk is divided into the chest, or *thorax*, and the *abdomen*.

In the human body there are three important cavities; namely, the cranial (brain case), the thoracic, and the abdominal. In

the cranial cavity is found the brain, the base of which passes through a large opening (Figure 392) to continue as the spinal cord of the central nervous system. The thoracic cavity contains a pair of lungs and the heart. This cavity is separated from the abdominal cavity by the diaphragm (Figure 395). In the abdominal cavity are the stomach, intestine, liver, kidneys, and reproductive organs.

321. Skeleton. — You remember the skeleton of the crayfish was on the outside of the body. In the fish and the frog you were introduced to the internal skeleton; the position of the skeleton in the fish, frog, bird, and mammal (including man) is the same, and is one of the important ways in which we recognize that an animal is a vertebrate. The skeleton of man, because of his erect position, seems at first sight to be very different from that of the dog or horse, but if we examine the parts carefully, we see that they are really quite similar. There are more than two hundred separate bones in the adult human skeleton.

The bones of the skull are (1) the cranium proper, which is the bony case that surrounds the brain, and (2) the bones that form the skeleton of the face. In the adult skull the bones have become fused and their outline is often recognized with difficulty. In early youth the joints between the bones are movable and allow for growth. The arched structure of the skull gives it great strength and thus makes the brain the best protected organ in our body. The deep sockets in the front protect the



Henry W. Stiles

FIGURE 393. INTERIOR OF SKULL, WITH
BACK OF CRANIUM REMOVED

eye. The important parts of the ear with all of its delicate portions are inclosed and are thus completely out of danger.

The bones of the face are mostly paired. The prominent cheek bones are just below the eye sockets and are separated by the bones of the nose. The upper and lower jaws containing teeth constitute the remaining important bones of the skull.

The spinal column consists of thirty-three segments or *vertebræ*. The different *vertebræ* permit a limited amount of movement which enables us to turn and bend the trunk in various directions. At the same time these *vertebræ*, piled one on top of another, constitute a strong support for the weight of the body and head. These *vertebræ* also have another important work as they surround the spinal cord and thus give protection to this portion of the nervous system.

There are twelve pairs of ribs. These are slender curved bones with one end attached to the verte-

FIGURE 394. SPINAL COLUMN

bræ of the back and the other end attached, directly or indirectly, to the sternum (Figure 395). The attachment of the ribs to the sternum is in part by flexible cartilage. This permits the freedom of movement necessary in breathing.

The breastbone or sternum in man consists of a single piece and serves for the attachment of the ribs and to protect the heart. In childhood this bone consists of several distinct parts.

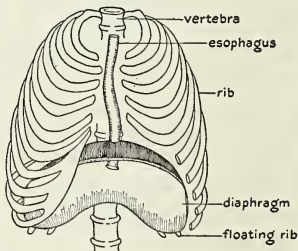


FIGURE 395. RELATION OF THE DIAPHRAGM TO THE RIBS

Between the ribs there are intercostal muscles that assist a person in breathing.

The arm and the leg of man are built upon the same plan. In the arm there is the long bone, which extends from the shoulder to the elbow, the two bones in the forearm, the row of small bones in the wrist which move freely upon each other, and the bones of the fingers. Similarly, there is the long upper part of the leg that extends from the hip to the knee; then, there are the two bones that go from the knee to the ankle, the several bones in the ankle, and the bones of the toes. The knee cap is an extra bone (Figure 391).

Two bones join the arms at the shoulder. One of these, the collar bone, connects the upper end of the sternum with the shoulder. The second bone is the shoulder blade, which is a large flat bone on the back of the shoulder serving as a most important surface for the

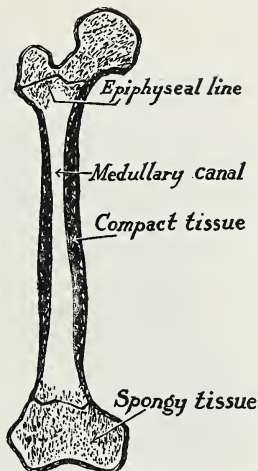


FIGURE 396. LONGITUDINAL SECTION OF A BONE

attachment of the powerful muscles that are partly responsible for the movements of the arm.

The hip girdle joins a number of the vertebræ which have become fused, furnishing thus a firm base of support for the body and at the same time permitting a large range of movement in the legs.

322. Bone and Cartilage.

— The skeleton appears first in the form of cartilage or of membrane, both of which are

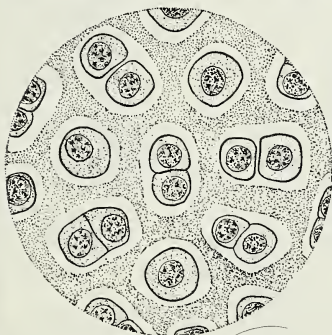


FIGURE 397. CARTILAGE

Note that the living cells are separated by an intercellular substance.

gradually replaced by true bone. This transition from soft material to hard bone begins before birth and is not completed in



FIGURE 398. DEVELOPMENT OF BONES IN THE HAND

The X-ray picture of a child's hand, at the left, shows that the bones of the wrist are not fully formed. The small bones in the joints later unite with the larger bones. The hand at the right is that of an adult.

certain bones before the twenty-fifth year, when some of the cartilage becomes hard bone. Cartilage occurs near the ends of the bones, in the ear, and in the nose. It is especially prominent in the wrists and ankles of children. Therefore, young children should not be lifted by their hands or allowed to stand until a certain amount of bone has taken the place of this soft cartilage.

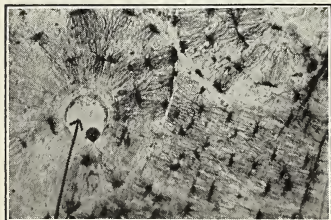


FIGURE 399. PHOTOMICROGRAPH OF A CROSS SECTION OF BONE

The arrow points to a Haversian canal, a channel for capillaries. The black spots and fine black lines are reservoirs and small canals connecting with the Haversian canal around which they are grouped.

There are cells in the bones just as there are cells in the liver, the muscles, and the nervous system. Like the other

parts of the body, the bones grow because the individual cells are supplied with food from the blood.

323. Mending Broken Bones. — Man has never been free from accidents. He is rarely injured by wild animals and only occasionally by domestic animals; but he frequently falls or slips, or is in some accident. The first measure taken to learn the extent of his injury is to have the bones photographed by X-rays. This gives an accurate picture of the injury (Figure 400), which enables the surgeon to proceed

in an intelligent manner. When the bones of a limb are broken, they are set, *i.e.*, the broken ends are brought to-

gether, and the limb is placed in splints or a cast to keep them from slipping. The protective splint must be left on until new bone forms and has time to harden.

324. Joints. — Wherever two bones meet, the place is termed a *joint*. The joints are divided into three classes: immovable joints, movable joints, and mixed joints. *Immovable joints* (sutures) are found in the skull of the adult. The bones of the skull do not become firmly united until the head has reached full size, after which no movement takes place between these bones.

Movable joints are the ball-and-socket joint in the shoulder and hip and the hinge joint in the elbow, knee, and ankle.

The mixed joints are those of the spinal column, which allow only a limited movement.



FIGURE 401.
X-RAY PICTURE OF
A DISLOCATED FINGER JOINT

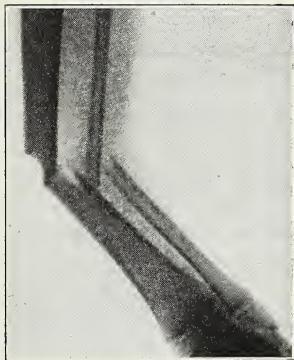


FIGURE 400. X-RAY PICTURE OF A
BROKEN ARM

The bones of movable joints are bound closely together by strong bands of cartilaginous tissue. These bands are called ligaments. The tearing or stretching of these ligaments is called a sprain.

LABORATORY STUDY

Study the skeleton, and examine long, flat, and irregular bones. How is the bone modified to do its work?

By means of a manikin, models, or organs of an animal, observe the general structure of the principal organs of the body.

STUDENT REPORT

Using the following form, make a report on the skeletal structures of animals on a separate piece of paper. Do not mark your book.

ANIMAL	ABSENT	JOINTED	NOT JOINTED	HORNY	BONY	INTERNAL	EXTERNAL
Paramecium							
Crayfish .							
Clam . .							
Frog . . .							
Man,							
etc. . .							

325. Muscles. — Muscles are of two kinds: *voluntary* (governed by the will), such as those which we use in walking or in moving the arms (Figure 406); *involuntary*, such as those that move the food along the digestive tract or assist in breathing.

The voluntary muscles consist of many long muscle cells (fibers) bound together by connective tissue into a distinct bundle. Usually the muscle bundle is attached at each end to the bones by a tendon of connective tissue (Figure 405). A single muscle moves the arm in one direction only, and in order to lift the arm from the desk to the head, for instance, several muscles must act together.

The cells of the involuntary muscles are unlike the cells of the voluntary muscles. Involuntary muscle cells occur in layers

in the walls of the digestive tube, blood vessels, the bladder, and the like, and they are not under the control of the will.

The muscular tissue of the heart has characteristics of both voluntary and involuntary muscles, so that it may almost be said to belong to a special class.

326. Nerve and Blood Supply of Muscles. — The muscles are richly supplied with numerous blood vessels, large and minute, and it is the blood that gives the deep red color to muscles. In recent years scientists have discovered that each muscle fiber is supplied with a fine branch of the main nerve that enters the muscle. This important fact enables us to understand how the nervous system controls our muscles.

327. Food of Muscles. — The blood flowing through the muscles carries food to the muscle cells. *Glycogen*, the sugar stored in the liver, is brought to the muscles by the blood and furnishes energy to the contracting muscles.



FIGURE 403. INVOLUNTARY MUSCLE CELLS

A small amount of fat is present in muscles and may be used up during their contraction. Under ordinary circumstances the protein foods do not furnish energy for contraction, but are used to repair the actual wastes that take place in the muscle cells as they work.

328. Action of the Voluntary Muscles. — When you place your left hand around the upper right arm and raise the right forearm toward the shoulder, you feel the muscle under the hand

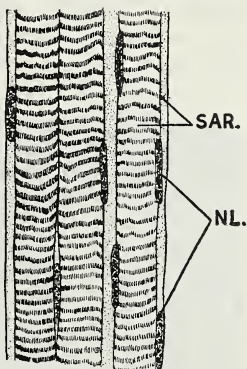


FIGURE 402. DIAGRAM OF A VOLUNTARY MUSCLE OF A FISH

Sar., sarcoplasm or muscle cytoplasm; *nl.*, nucleus. Compare with Figure 403.

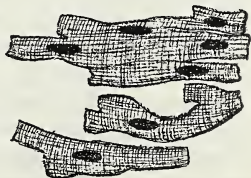


FIGURE 404. HEART MUSCLE CELLS

become shorter, thicker, and firmer. This is the biceps muscle, which one writer states is made up of possibly 260,000 voluntary muscle cells held in place by connective tissue. These cells must receive a message from the brain if they are to contract. Each cell in a muscle contracts as hard as it can when the order from the brain is given. But we can move our forearm slowly

or rapidly, and the difference seems to depend on the number of muscle cells that we can order to contract. We may order 100 or 1000 of the cells in the biceps to contract and we can combine them with as few or as many cells in other muscles as we like. We rarely ask all of the cells in any of our muscles to pull for us at the same time. When you stand on your feet and throw a baseball, you use parts of almost every muscle in your body. If you wish to throw the ball faster, you call on a few hundred thousand more muscle cells than you have been using when you threw a slow ball. Each of us has

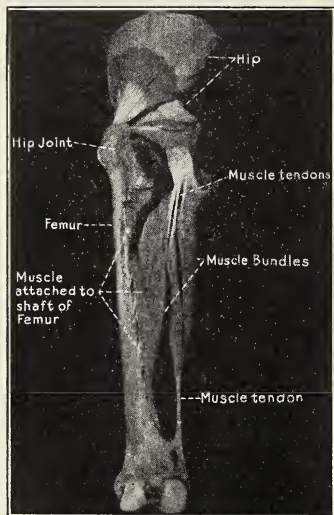


FIGURE 405. HIP AND THIGH MUSCLES

already learned to use certain combinations of muscles when we wish to accomplish a given result.

329. Fatigue of Muscles. — When you are feeling well, your muscles respond quickly to your desire to walk or run. If you are accustomed to regular exercise, your muscles respond even more quickly, but after playing hard or working at any hard physical task, you become tired and need to rest. The muscles are fatigued. When you are taking your physical exercises, some of the movements make your arms ache, and you do not do them

in good form. You are using muscles that do not get much exercise and they quickly become fatigued. You may continue to move your arm until it is impossible to move it any longer. What really happens? Each time that you move your arm, heat and lactic acid (the same acid as in sour milk) are produced and work is done. If you move your arm long and hard enough, even without lifting or pushing anything, you soon begin to perspire from the heat produced. During this muscular work some of the glycogen brought to the muscle by the blood is changed to lactic acid. As this change takes place, heat is produced and the muscle cells contract. Therefore the cause of the fatigued muscle cells in your arm is too much lactic acid.

You recover from this fatigue by changing some of the lactic acid back into glycogen. Oxygen is necessary for this process as well as for the formation of lactic acid from glycogen. Some of the lactic acid is changed into carbon dioxide and water. As the lactic acid is changed back to glycogen, your muscle ceases to be tired. After exercise you feel the need of oxygen and breathe deeply and rapidly until this extra demand is supplied.

Every one has had the experience of being able to sprint for a short distance at a rate that would utterly exhaust him if kept up for a long distance. Some of the famous runners have been tested to see how fast they could run, and their oxygen intake has been measured. In a 100-yard dash, the oxygen debt may be as great as an ordinary man would breathe in one quarter of an hour.

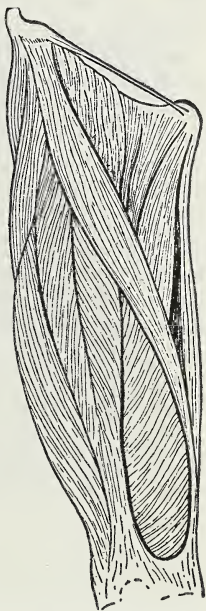


FIGURE 406. THIGH MUSCLES

The arrangement in bundles is an adaptation that allows the leg to be moved in many directions.

It is not enough to get the oxygen into the body. It must be carried to the muscles. In the trained individual several factors aid in increasing the flow of blood to the working muscles. First, the output of the heart increases six to nine times. Secondly, the walls of the large blood vessels in the abdomen contract, and those of the skin and working muscles relax so that more blood enters them. The result is that the flow of blood through an active muscle is six to eight times greater than through the same muscle at rest.

If you have been using your arm only an ordinary amount and then exercise it a good deal, as you frequently do in early spring, the muscles become stiff and sore. This is due to the excess of lactic acid and carbon dioxide. The soreness can be relieved by rubbing and heat. The rubbing helps to increase the circulation, and the heat relaxes the blood vessels so that they receive more blood with more oxygen to act with the lactic acid and to remove the waste product, carbon dioxide.

330. Importance of Exercise. — Now that we are beginning to understand how a muscle utilizes food energy in doing its work and just what is meant by *fatigue*, we can better analyze the need for exercise. At this time the effects on the muscle will be stressed. First, there is a natural increase in the size of muscles when the exercise is systematic and properly adjusted to the needs of the individual. Secondly, a muscle that is exercised increases in power because it is larger and all of its cells are made to act together. Thirdly, there is an improvement in muscular control. When you begin to play tennis or some other game, you are unable to bring accuracy into your efforts, but after a short time there is a marked improvement in the muscle tone, which is the quality of the reaction in the muscle. A flabby muscle has poor tone.

The recreative forms of exercise such as basket ball, tennis, baseball, football, and rowing are valuable for the general health and are good for the development of muscle. But we should not indulge in violent exercise except after careful training, which should always be preceded by a thorough physical examination.

All persons have the same number of muscles, more than 500, attached to the same parts of the skeleton. In every case of physical unfitness, then, the deficiency must consist in the training which the individual has given to these muscles.

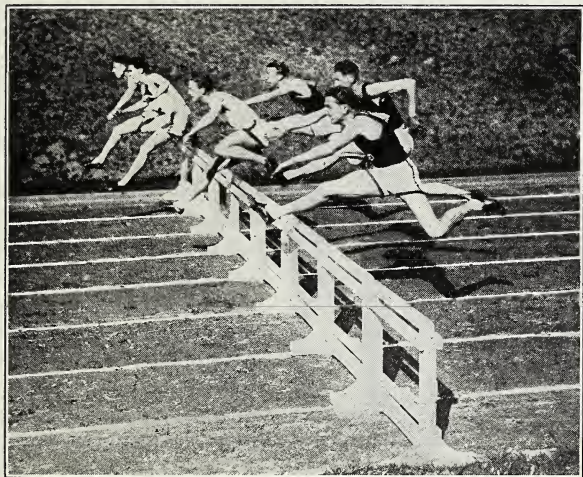


FIGURE 407. HURDLERS

The position of the arms and body as the hurdler springs over the hurdle assists in giving additional speed. Notice the positions of the legs. The remarkable speed with which one can make all of the necessary adjustments is a constant source of wonder, for nearly all of the 500 muscles in the body are called into action in this picture in less than a second of time.

The human body not only is very delicately adjusted and balanced but permits of a great variety of movements in the work performed. The muscles are subjected to varying degrees of strain, which have their influence not only on the organs of the chest and thorax, but upon the higher mental processes as well. Less energy is required in the correct use of the muscles than in the incorrect use of them.

Sitting. — More and more time is being devoted to work

carried on in a sitting position. The correct sitting position is that with the trunk of the body straight, resting squarely on the hips, and not sliding down into the seat. The trunk should be kept at right angles to the long bones of the leg. It is easier to sit correctly in a shallow than in a deep seat. One can also sit correctly so far as the trunk is concerned and still become fatigued by bending the head too far forward at the neck.

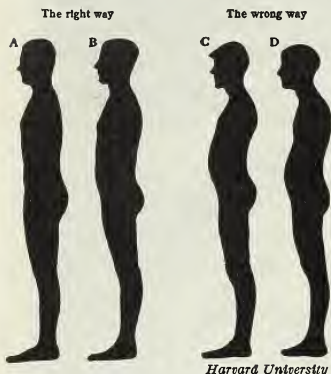


FIGURE 408. BODY MECHANICS

A, excellent; B, good; C, poor; D, very poor.

of the muscles. The defects caused by incorrect position of the body require very definite exercises to correct them.

Walking. — Walking is a pleasure when the whole body is in correct position and the weight thrown forward on the ball of the foot. The feet should point forward instead of at an angle. It is easy to practice correct walking by simply holding the body in proper standing posture, and then walking forward along a line, each step of the foot directed forward with the front foot close against the toes of the rear one.

331. Mental Attitude. — Our mental attitude has much to do with our posture. How much straighter we stand when we are cheerful than when we are dejected! And our posture also reacts on our mental attitude. When we are gloomy and down-

cast, we can often make ourselves more cheerful by standing erect and taking a brisk walk in the fresh air, breathing deeply and throwing out our chests.

332. Hygiene of the Foot.

—The human foot is an ingenious arrangement of bones, muscles, and tendons, which support the weight of the entire body. There are two arches in the foot, one in the forward part, the *anterior metatarsal*, and the other running lengthwise, called the *longitudinal arch* (Figure 409). Both of these arches act as shock absorbers and they must be in perfect condition for the feet to work properly. If, as often happens, one arch is depressed or broken down, we get what is called *flat foot*. It usually causes a feeling of unusual fatigue and weariness at night.

Flat foot may be prevented by using a little care. The proper method is to walk with the feet parallel, not with the toes pointed out. Walking with the toes pointed straight ahead strengthens the muscles.



FIGURE 409. X-RAY PICTURES OF FOOT OF GIRL WEARING PROPER SHOE (*above*) AND HIGH-HEELED SHOE (*below*)

Raising the heel weakens the muscles at the back of the heel and strains the muscles of the arch of the foot. Such shoes are a source of much discomfort, and should not be worn if one wishes to be well.

SUMMARY

The skin protects the soft parts of the body from minor injuries. The skeleton of man protects our sense organs and nervous system from injury and shock; it also serves as a firm attachment for the muscles, some of which are constantly at work. Every movement that we or any animal makes must have energy, and this energy comes from the food eaten. It is by means of

movement that we recognize that an animal is alive. Although man is able to move about like other animals, many of them can move faster in the water, on land, or in the air. They also move by means of muscles attached to their skeletons acting under the supervision of the nervous system. Bones grow and are fed like muscles or any other tissue in the body. The bones of the skeleton move by means of joints which are held in place by ligaments. Bones grow new bone, as in the broken femur. There is a definite plan of structure in all bones.

Physical training develops properly all the muscles of the body, keeps it well, and makes it as strong as possible. Correct posture is important to health and depends partly upon mental attitude. The feet should be cared for, especially in the selection of proper shoes.

QUESTIONS

How does the skeleton of man compare with that of the crayfish? How do bones grow? Why do they grow? Where is there the most cartilage in our skeletons? What are joints? What is a sprain? How do broken bones heal? How does muscle differ from bone? How many kinds of muscles are there? What is the work of each? Why are muscles important? What is the relation of the nervous system to muscles? What is the importance of the blood vessels to the muscles? Explain how the different foods are used by muscles. What is the value of physical training? How does good posture help you?

TOPICS FOR DISCUSSION

1. Compare the position of the legs of man with the position of the legs of the horse or dog. What are the advantages and disadvantages?
2. Is the arm of man more highly specialized than the arm of the frog, bird, or bat?
3. To what extent can any animal except man place the thumb opposite his fingers? How important is this ability?
4. "Long slender hands indicate an artistic nature." Is this true?

REFERENCES

See list of books on page 505.

CHAPTER XXXI

TRANSPORTATION SYSTEM

*When life leaps in the veins, when it beats in the heart,
When it thrills as it fills every animate part,
Where lurks it? how works it? we scarcely detect it.*

—MEREDITH

333. Methods of Travel. — We do not know when man discovered that he could make some animal carry his loads, but some time later he invented a wheel and the development of carts, wagons, automobiles, and airplanes followed. Today we have a transportation system which connects us with all parts of the world. When there is a threatened strike on our railroads, we wonder how long the food supply in our cities will last. Our various transportation systems not only supply us with food but also carry away the garbage, two absolutely necessary processes. Similarly, the body of man has a complete transportation system which serves the same purposes.

334. Methods of Travel in Our Bodies. — The simple protozoans do not require specific structures to carry food to all parts of their bodies, and their garbage is dumped into the surrounding water. The hydra, composed of many cells, lacks anything resembling blood, heart, or arteries. But these minute animals never grow to large size or move continuously for a definite period as a fish does. Wherever we have relatively large, active animals, such as earthworms, crayfish, and vertebrates, there is to be found within each a more or less elaborate transportation system.

We realize that our bodies are made up of a very great number of cells and that most of these are hidden away in muscles, brain, liver, heart, blood, and other organs. In order that all of these may be supplied with food and their waste products removed,

a very elaborate transportation system is necessary. The names of the several organs of our transportation system are the heart and blood vessels, the respiratory organs, and the excretory organs.

In every transportation system which man has invented, there are stations for getting on and off, but in the one that nature has fashioned for our bodies, the blood continues to move from the heart to the other organs in an endless stream, one drop requiring

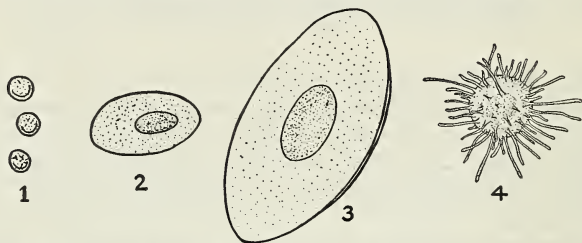


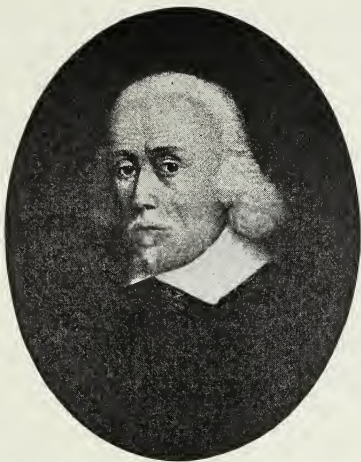
FIGURE 410. BLOOD CELLS OF DIFFERENT ANIMALS, ENLARGED PROPORTIONATELY 1, red cells of man; 2, red cell of frog; 3, red cell of mud-puppy; 4, white cell of cabbage butterfly.

about 30 seconds to complete its circuit back to the heart. In a similar manner, oxygen keeps moving with the air taken into the lungs and after it has entered the blood; there is no general storehouse for oxygen within our bodies. There is likewise a continuous formation of wastes which are removed by the kidneys.

While we shall describe each of these transportation processes separately for the sake of clearness, we should think of them as depending on each other and one leading into another with no sharp line of distinction, all being phases of our life.

335. Blood. — Blood is a fluid which circulates through the heart, arteries, and veins, supplying nutritive material to every part of the body. It is made up of a fluid (plasma) which contains cells or corpuscles.

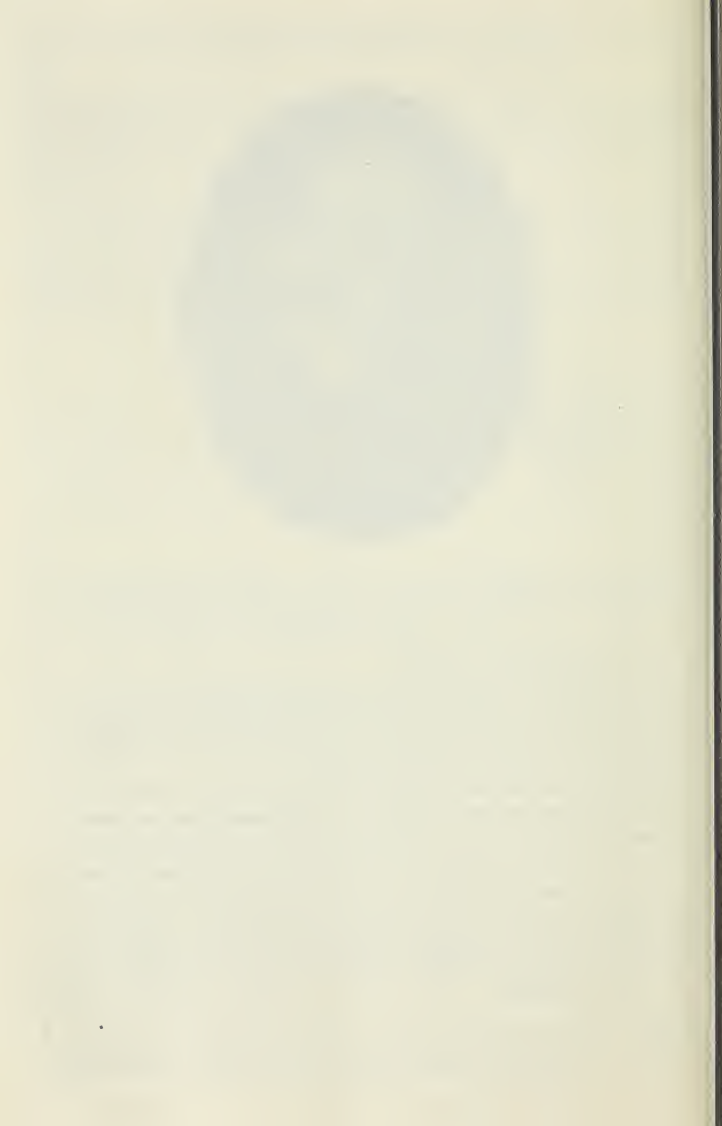
The *red corpuscles* are colored with a substance called *hæmoglobin*. When a few of these corpuscles are examined through a



WILLIAM HARVEY (1578-1657) began his studies at a period when science was not in good standing. The study of the structure of the human body was just being undertaken anew after a period of nearly twelve hundred years of neglect.

He was a very industrious student and his great classic was the result of many years of painstaking dissections. A free translation of the title of his book gives us the following: *An Anatomical Disquisition on the Movement of the Heart and Blood in Animals*.

Harvey was the first to describe the blood as moving in a circuit in the body and to state that the beating of the heart supplies the propelling force. After his brilliant dissections, man learned the difference between a vein and an artery and learned how to stop bleeding. Harvey also made notable contributions to knowledge about the development of animals and their activities. True ideas about secretions, respiration, and the distribution of food in the body began as soon as the exact course of the blood was known. This is why Harvey's discoveries are of such importance.



microscope, they appear yellowish instead of red; but when a large number of them are seen in a mass, the red color is apparent. When the red cells are first formed, they have nuclei which gradually disappear. As a result, the mature red corpuscles, unlike all the other cells we have studied thus far, have no nuclei.

The red corpuscles carry oxygen from the lungs to the cells of the body. As soon as the oxygen in the inspired air enters the blood, it unites chemically with the hæmoglobin contained within the red blood corpuscles. Here it remains until it reaches cells that are deficient in oxygen, when it passes by osmosis from the blood to such cells. These cells take the oxygen and use it in the process of oxidation, which goes on continuously in every living cell. A good supply of red blood corpuscles is, therefore, necessary if the cells of the body are to have a sufficient supply of oxygen.

At the same time that oxygen is received from the blood by the body cells, carbon dioxide is given off. Again osmosis explains the method of this transfer. Most of the carbon dioxide is carried by the plasma, although some of it unites with the hæmoglobin.

The *white blood corpuscles* are a little larger than the red and are much like the ameba in that they are colorless and can change their form. They move about in the body and when necessary leave the blood vessels and collect at one place to aid the body in destroying disease germs. The white blood cells eat these disease germs just as the ameba or paramecium eats bacteria.

The blood plasma has its source in the liquids taken into the body. It is straw-colored and varies in composition from day to

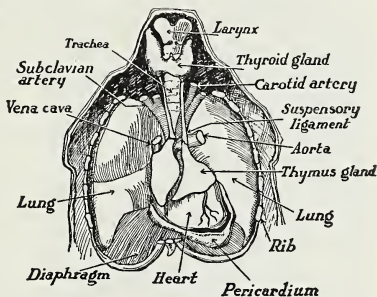


FIGURE 411. DIAGRAM OF CHEST CAVITY

day, and from hour to hour. It contains the foods on their way to the cells, and waste products on their way to the kidneys, lungs, and skin. The volume of blood in the average person is about six quarts.

336. Clotting of Blood. — When the blood is exposed to the air, it forms a clot. This is a peculiarity of blood. If it were not for this property, animals would bleed to death from even a slight cut. In some warm-blooded animals, the blood clots more quickly than in man. Man is able, by pressing upon the blood vessels or by tying them, to assist the process of clotting and prevent hemorrhage (hēm'ō-rāj). Naturally the blood does not clot except when exposed to the air, when fibrin threads are formed from the fibrinogen (fī-brīn'ō-jěn) contained in the plasma of the blood. These threads hold the red and white corpuscles. After a short time the whole mass shrinks, squeezing out the fluid part of the blood, and the semi-fluid mass that remains is the clot.

337. Temperature of the Blood. — The normal temperature of the body of an adult is about 98.6° F, although there are a few healthy persons who regularly have a temperature below or above this average. This is known as *blood heat*, since it is maintained evenly throughout the body by the blood. This temperature may be lowered in the ears, fingers, toes, and nose by exposure, and it may be raised all over by fever; when it is higher than 98.6°, the patient is said to "have a temperature," and it is a sign that something is wrong.

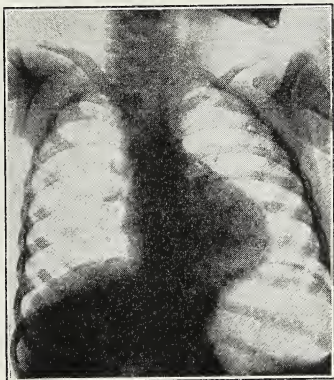
338. The Work of the Heart. — The heart pumps the blood to all the cells of the body and back again and again. The heart is about the size of the fist and has strong muscular walls. In a healthy person, it contracts about seventy times a minute.¹

¹ "The work the heart does during the day is about equal to the energy expended by a man in climbing to the top of a mountain 3600 feet high. Assuming that the man weighs about 150 pounds, this would be equal to an amount of energy sufficient to lift 90 tons to a height of three feet. The work of the left side is greater than that of the right, since the former has to drive the blood all over the body, while the latter has only to force it to the lungs, which are near by. For this reason the muscle walls of the right ventricle are much thinner than those of the left ventricle." — CONN AND BUDDINGTON.

The heart is located in the *thoracic*, or chest, cavity, a little to the left side and between the lungs. (See Figure 412.)

The Pulse. — Every time the heart beats (contracts), the blood is forced into the arteries in a wave which can be felt in the wrist or neck by placing the finger over an artery. The wave is called the *pulse*. By counting the number of waves in a minute, we determine the rate at which the heart beats. When a person runs or takes violent exercise, the pulse rate increases. A similar increase in the pulse rate occurs when he becomes angry or excited.

Closely associated with the pulse is the additional condition known as *blood pressure*. Blood pressure is the force with which the blood pushes against the walls of the arteries with every heart beat. Special appliances have been devised which accurately measure the amount of this pressure. The information thus revealed to the physician is often very important.



Carlton F. Potter

FIGURE 412. X-RAY PICTURE OF CHEST REGION

The heart is shown in dark outline.

HOME PROJECT

Experiments on Pulse Rate. — Count the number of beats a minute by placing the fingers on the wrist. You will need to repeat this count several times because you are not experienced in such observations. It is best to make the count on some one other than yourself. After you have been able to get about the same number of pulse beats a minute in two counts, have the person run upstairs or hop on one foot fifty times, then make your count again. How does it compare with the previous count? Compare the rate of the pulse when standing, after sitting a short time, when lying down, and the first thing in the morning. If you were to have your pulse

taken just after getting angry or excited, you would find that it has increased over its regular rate. What conclusions do you draw from these observations on the pulse?

339. Circulation. In order to understand the process of circulation, the meaning of three words must be clearly defined. *Artery* is the name given to the blood vessels which carry blood from the heart. *Vein* is the term applied to the vessels which return blood to the heart. There is little structural difference between the veins and arteries except that the walls of the arteries

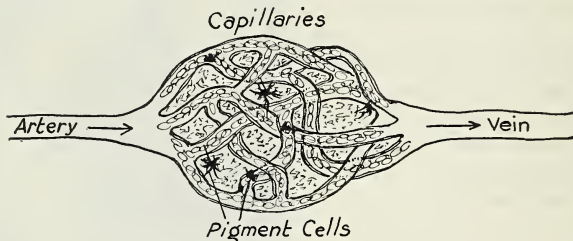
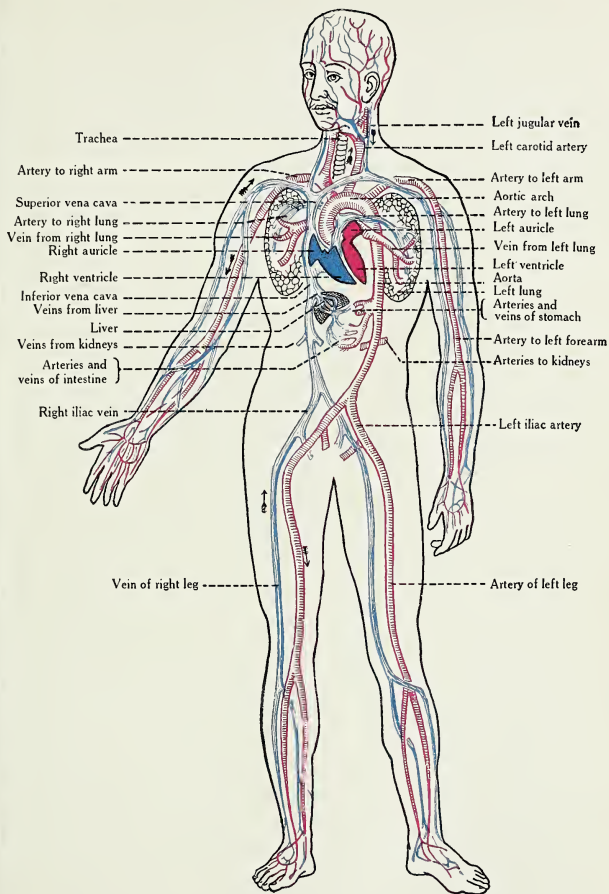


FIGURE 413. CAPILLARIES

are thicker, and there are no small valves as in the veins. As the branches of the arteries become minute, the walls consisting of a thin, epithelial coat allow the food and oxygen to pass more easily to the individual cells. These minute branches are called *capillaries*. (See Figure 413.)

Pulmonary circulation. — The *right* ventricle, after it receives the blood from the *right* auricle above, contracts and forces the blood into a lung artery which forms two branches. (Study the color plate.) One of these goes to the right lung and the other to the left lung, and each divides in the tissues of the lungs until the blood is forced into minute capillaries. It is in these small capillaries in close contact with air spaces that the blood receives its new supply of oxygen and gives off its carbon dioxide. Finally the blood flows from these capillaries into veins which unite eventually and return the blood to the left auricle.

This is the pulmonary circulation, and by it the blood is



THE CIRCULATION OF THE BLOOD IN MAN



purified, *i.e.*, it loses much of the carbon dioxide and secures a fresh supply of oxygen. Its color changes from a bluish red to a bright red.

Systemic Circulation. — The blood is forced from the left ventricle through the aorta, the largest one of the arteries. From the aorta come branches which penetrate every organ in the body.

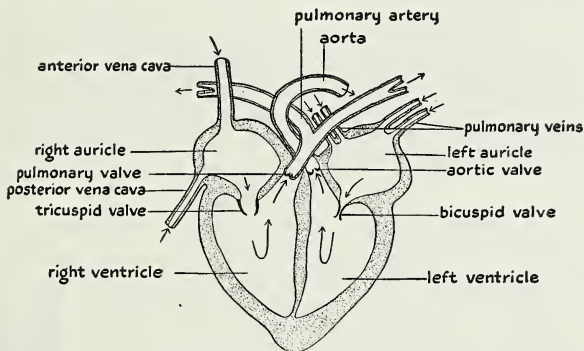


FIGURE 414. DIAGRAM OF HEART

(Study the color plate.) After the arteries enter the organs they divide into capillaries, which pass into all the cells of the body and supply them with oxygen and foods in solution. The capillaries are so very numerous that in a piece of muscle with a cross section the size of an ordinary pin, there are about eight hundred of these microscopic blood vessels. A recent investigator states that the blood vessels of an average-sized man, if placed in a continuous straight line, would reach around the globe two and one half times. Because of their great numbers and consequent large surface, the capillaries can carry nourishment and oxygen to the tissues, and readily remove the waste. The capillaries conduct the blood from the arteries toward the smaller veins, which then become larger after the manner of the river system which is filled up by numerous tributaries. Eventually these veins carrying the blood toward the heart reach the right

auricle through two main veins. This is the systemic circulation, and during the movement of the blood it has given up much of its supply of oxygen and lost much of its food value, which has been taken from it by the cells.



FIGURE 415. DIAGRAM OF ARTERY, CAPILLARIES, AND VEIN

As the blood flows through the capillaries of a voluntary muscle, for example, oxygen and dissolved food are given off to the muscle cells, and carbon dioxide and other wastes pass from the cells into the blood.

Portal Circulation. — The portal circulation includes the portion of the systemic circulation which courses through the liver and digestive regions and then returns to the heart. In the liver the blood takes up foods in solution.

Thus it will be seen that the composition of the blood changes as it passes through the various organs of the body, such as the skin, muscles, and stomach. The capillaries supply the substance necessary for the secretions of the glands; in the small intestine they absorb the elements of digested food; in the lungs they take up oxygen and give off carbon dioxide; and in the kidneys they throw off the waste products they have collected.

Lymph. — As the blood flows through the capillaries, part of the plasma passes through the thin walls into the spaces between the cells and bathes the cells. This fluid which escapes from the capillaries is called *lymph* (lĭmf). It is composed of digested food, water, and other substances. The cells assimilate the food which they need and cast back into the lymph the wastes which they have formed in the process of growth and repair. The spaces between the cells are small and irregular in shape but they form a sort of mesh, or net, the parts of which join, making larger vessels, and finally all the lymph is collected into two large vessels which open into veins.



FIGURE 416.
VALVES IN A
VEIN

Thus there is the *lymphatic circulation*, which differs from that of the blood in several ways. (1) There is no special organ for forcing the lymph along, the circulation depending mainly upon the movement of the muscles. (2) The lymphatic vessels are imperfect in the beginning, being only irregular spaces. (3) The lymph contains no red corpuscles and only a few white corpuscles.

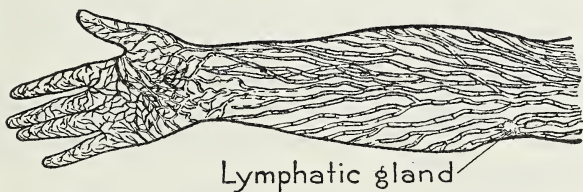


FIGURE 417. SUPERFICIAL LYMPHATICS OF ARM AND HAND

340. Cuts. — Since blood vessels traverse every part of the body inside the skin, we cannot injure any part without breaking some of them. A small cut causes the blood to flow only from capillaries, and it flows slowly and in small quantities. If a vein be cut, the blood will be dark in color, and will flow in larger quantities, but steadily. A severed artery sends out bright red blood in waves corresponding to the beats of the heart. To stop the flow of blood from a vein, compress the vein beyond the cut; to stop the flow from an artery, compress the artery between the cut and the heart. In either case remain quiet to aid the blood to form a clot.

341. Exercise and Circulation. — The object of a circulatory system and of a circulatory fluid is to supply every cell in the body with food and to carry away the waste. The more active the process of circulation, the more perfectly is this object accomplished. It is common experience that the heart beats more rapidly, the lungs work harder, and the body becomes warm after a few minutes of vigorous exercise. These changes have a decidedly beneficial effect upon building up the body and removing the wastes.

342. Fainting. — Fainting is due to an insufficient supply of blood in the brain. This lack of blood may arise from several causes, but the most common is some disturbance of the digestive processes, which causes the heart to beat too slowly. A fainting person should be placed flat on his back, if possible, with his head slightly lower than the rest of his body, and should be given plenty of fresh air. A dash of cold water in the face, or a bottle of ammonia held to the nostrils, is often helpful in restoring consciousness.

343. Respiration. — This is the process by which oxygen unites in living cells with that part of the protoplasm containing available carbon and hydrogen, thus supplying the energy for various life processes.

STUDENT REPORT ON RESPIRATION

Copy this form and enter the information on the copy. Do not mark your book.

ANIMAL	GET OXYGEN		GET RID OF CARBON DIOXIDE			BREATHE THROUGH		
	Water	Air	Water	Air	Skin	Gill	Lung	Air Tubes
Ameba								
Crayfish								
Fly								
Toad								
Bird								
Man								

344. Human Organs of Respiration. — In an animal like man, composed of a great many cells, the oxygen must be transferred by special mechanisms as it is impossible to bring each cell into direct contact with the oxygen of the air. These mechanisms are the organs of respiration and of circulation and the hæmoglobin of the blood. The air enters the nose and passes into the windpipe or trachea. The opening into the windpipe is covered by the *epiglottis*, which is raised during breathing and closed when food is swallowed. This leads into the *voice box* or *larynx* (lăr'īŋks)

which is found just below the opening into the windpipe. The stiff cartilage which protrudes in front is often called "Adam's apple." The larynx is formed by several large pieces of cartilage lined with a mucous membrane. On the inside of the larynx project two folds of elastic tissue which are called the *vocal cords*. The windpipe divides into two branches, one entering each lung. Each branch is called a *bronchus*. The windpipe and bronchi are the passages through which air is carried to the lungs. These passages are kept open by numerous stiff cartilage rings, which, in the trachea, are not entirely complete on the side of the esophagus, and in the smaller tubes even less so.

As each bronchus enters the lung, it divides into branches which in turn branch out again and again, until the entire lung is penetrated in all its parts by these passages. Finally each branch ends in a small pouch-like sac called an *air cell* or *air sac*. The walls of the air cells are thin, and the cells themselves are surrounded by minute branches of the blood vessels. The walls of the bronchi are highly folded. All these thin walls of the lungs and blood vessels are adapted to the passage of oxygen into the blood. They are equally well adapted to getting rid of various wastes such as carbon dioxide, of excess water as water vapor, or of fumes from volatile substances.

345. Breathing. — The lungs are elastic and can be squeezed like a sponge. *Inspiration* is the term applied to the taking of air into the lungs, and *expiration* to the forcing out of air. The full capacity of the lungs is about 2000 cc. of air. The process

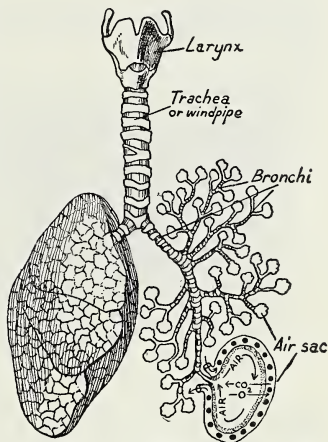


FIGURE 418. DIAGRAM OF THE LUNGS

of inspiration requires that the muscles of the chest do a considerable amount of work, as the cartilages attached to the ribs must be bent and the walls of the abdomen stretched. This contraction of the respiratory muscles increases the volume of the chest cavity, creating a lowered air pressure in the lungs which brings about an inrush of about 450 cc. of air that fills out the lungs.

As the respiratory muscles relax, the elasticity of the cartilages and the increased pressure of the abdomen force the air out gently.

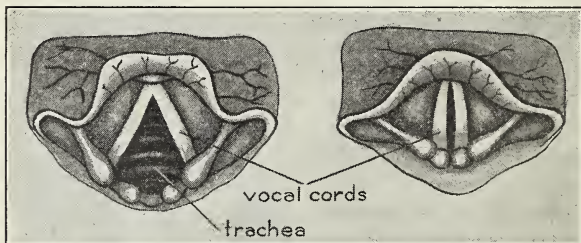


FIGURE 419. LARYNX

At the left, it is shown during respiration ; at the right, during speech.

About 450 cc. of air will thus pass out, leaving, in an adult, about 1500 cc. of reserve air still in the lungs. We can remove the larger part of this air from the lungs and replace it with fresh air by breathing deeply a few times.

The natural rate of breathing is about eighteen times a minute, but the rate is higher in persons with a small lung capacity. Exercise increases the rate of breathing. (Explain why outdoor exercise is better for us than indoor exercise.)

All the air passages are lined with cells bearing numerous cilia (Figure 420), and these cilia are constantly in motion. Their work is to carry toward the mouth the particles of dust and other foreign materials brought in by the air. This foreign matter is removed when we cough or clear our throats. (Explain why clean air is better for us than foul air.)

The purpose of breathing is to take the air, rich in oxygen, into the minute air sacs which are lined with a thin layer of *epithelial* cells. Capillaries penetrate the walls of these sacs. It is well to keep in mind that green plants are constantly, during the daytime, using carbon dioxide in manufacturing starchy foods and giving off oxygen, so that the air is being made better for animals and man to breathe, while at the same time these green plants are storing up food for animals, including man.

Systematic Exercise. — If we keep our bodies in correct posture, little need be said about breathing exercises. A great deal has been written about the value of deep breathing, but it is not necessary to continue to do this all the time. There is no question that it is desirable to be able to breathe deeply and to have a large chest if for no other reason than that it gives the heart more room in which to do its work. Lazy habits of breathing tend to weaken the muscles of inspiration, and the result is that only a part of the lungs is used.

The normal movements in breathing permit the ribs to be elevated as air is drawn into the lungs. Wearing tight clothing around the chest interferes with these normal movements and makes it difficult to get the required amount of oxygen into the lungs. Unless loose clothing is worn during exercise, the muscles used in respiration are not benefited by the exercise.

Suffocation and Artificial Breathing. — When the body is deprived of a sufficient supply of oxygen, suffocation results. This may be brought about by confinement in a small, air-tight inclosure, by inhaling poisonous gases, and by drowning. Whatever may be the cause of suffocation, the person should be at once brought into fresh air.

Persons suffering from suffocation can often be revived by artificially moving the muscles of the chest so as to imitate as closely as possible the normal breathing movements. There

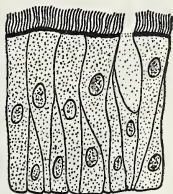


FIGURE 420. CILIATED EPITHELIUM

Such cells line our bronchial tubes. Explain their work.

are several well-known methods, of which the *prone pressure method* of artificial breathing is one of the best. The patient is placed with his face downward, having the cheek resting on one arm. The person attempting to stimulate natural breathing should kneel astride of the patient's legs and place his hands on each side of the patient's body opposite the lower ribs. He should press down and then forward, counting slowly "one, two, three."

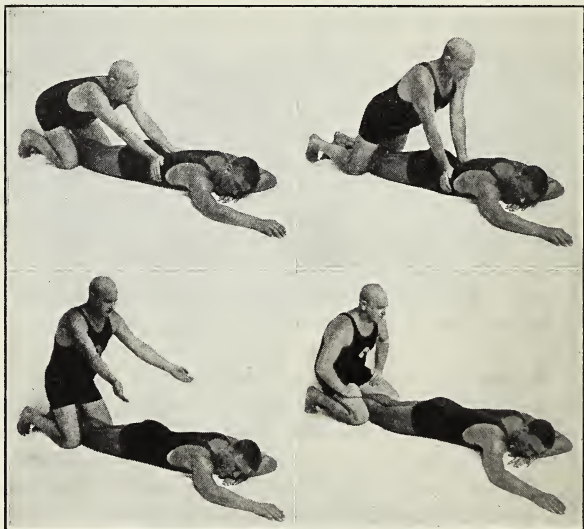


FIGURE 421. PRONE PRESSURE

This shows the four steps in stimulating artificial breathing.

He should then remove the pressure quickly, counting slowly, "four, five." This simple pair of movements should be repeated twelve or fifteen times a minute. The pressure helps to force the water from the lungs in the case of drowning. It imitates, as well as one can, the natural breathing movements, and should be continued, if necessary, for several hours.

346. Excretion. — In every city and nearly every small village there is a definite system of removing refuse. One set of wagons loads up the ashes and another type of wagon picks up the food wastes from our kitchens; in addition to these, there is the elaborate sewer system that removes the liquid wastes from our homes. So, in the body of every one of us are living cells, each of which lives and works; many of them die and are replaced by newly grown cells. The transportation system brings food to each and carries away its waste and ash.

The kidneys, sweat glands (page 418), and lungs are the chief excretory organs but the greater part of the elimination of waste substances is done by the kidneys.

347. Kidneys. — The kidneys are two bean-shaped organs located in the rear of the abdominal cavity, one on each side of the “small” of the back. Each is about four inches long, two and a half inches wide, and a half inch thick and red in color (Figure 422). These two organs are very efficient not only in removing wastes but also in keeping the composition of the blood constant. The structural unit in the kidney is known as a *tubule* and it is similar to a sweat gland, but longer and more highly specialized. In Figure 423 you can see that the blood vessels are intimately in contact with certain parts of the kidney tubule, and at these places the walls of the capillaries and the walls of the tubule are thin, which is similar to the conditions in the lungs. In the kidneys, liquid materials pass through the walls; and in the lungs, mostly gases. The several substances that are removed from the blood by the kidneys constitute the urine that collects in the bladder.

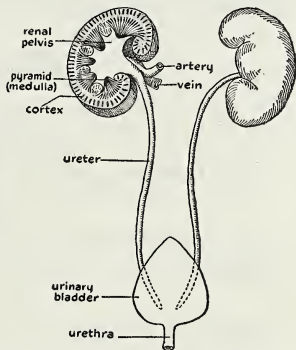


FIGURE 422. DIAGRAM OF THE KIDNEYS

348. Intestine. — The excretion wastes from the intestine are not easily defined. The several digestive secretions which are not absorbed may be regarded as waste products after they have caused the different digestive changes. Of these a small portion remains in the intestine. The bile pigments may be especially mentioned as excretions that pass from the body through the intestine. The excretions of the body should not be confused with the indigestible part of the food which is not

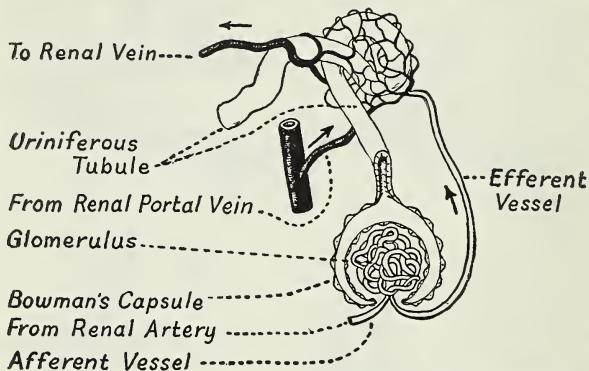


FIGURE 423. RELATIONS OF ARTERY AND VEIN TO KIDNEY TUBULE

taken up by the blood and which passes out through the large intestine as *feces* (fē'sēz). This process is called elimination.

The Necessity of Excretion. — Unless the several organs of excretion do their work properly the wastes of the body accumulate. These wastes are poisonous, and harmful results must follow if they are allowed to remain in the system. A skin which is not healthy cannot be expected to hold healthy nerve endings or to do its work as it should. Overeating or eating too much meat places an extra burden on the kidneys because the body absorbs only as much nutriment as is needed and can be stored as fat. The rest has to be removed, thus increasing the work of the kidneys. Regularity and moderation in eating, as in all

habits, are two excellent rules to follow. The removal of wastes from the body is influenced by the amount of water taken daily. There are few who drink enough water and very few who ever drink too much.

SUMMARY

The transportation system consists of three highly developed sets of organs that work in the best of harmony in every healthy person. The constant beating of the heart as it forces blood to every organ and cell does a great deal of work each day for us. Blood vessels and capillaries ramify in each organ until their entire length is incredible. All of the cells are bathed in a thin layer of lymph so that every substance that enters or leaves a cell passes through a fluid. The various foods that enter the blood from the intestine and the oxygen that enters through the lungs are equally at home in the blood. The blood maintains a remarkably uniform composition due to the regulation by the organs of excretion, kidneys, sweat glands, and lungs.

QUESTIONS

Compare the organs of respiration, circulation, and excretion in the animals that you have studied. In what important points do they agree? What is the difference between a lung and a gill? What is the source of wastes? Is it the same in a frog? Which life processes are affected by the transportation system?

SPECIAL TOPICS FOR DISCUSSION

1. Which animals lack a transportation system?
2. Which animals possess a transportation system?
3. Compare the efficiency of the two groups.

REFERENCES

See list of books on page 505.

CHAPTER XXXII

SUPPLY AND DEMAND

Thou shouldst eat to live; not live to eat.

— CICERO

349. Chemical Analysis. — We have described the work which the cells in our bodies do (page 48) and their constant demand for energy. In the study of the transportation system, we saw how complex animals, plants, and man have methods of carrying to all of the cells an adequate supply of energy.

There can be no satisfactory growth of any living thing unless each is supplied with the food that its particular body demands; if any part of the transportation system fails to work, the organs deprived of their supply of food slowly starve and die unless the system is repaired; and every living thing is dependent on weather conditions. The lack of rain for three or four weeks in June and July in the North temperate region accompanied by high temperature may almost destroy the normal growth of hay, oats, vegetables, and pasturage for domestic animals. Man is no exception to such fundamental processes. It is true that he can anticipate in a general way what will happen and try to make proper arrangements to meet the needs of summer and winter, but he cannot control weather conditions.

Like all other living things man is made up of chemicals (page 25). The number of chemical elements varies in different forms of life but all have certain ones which in man are combined in the following proportions:

oxygen	72 parts	nitrogen	2.5 parts
carbon	13.5 parts	calcium	1.3 parts
hydrogen	9.1 parts	phosphorous	1.15 parts

In addition to the six mentioned on page 458 the following are distributed in small amounts: silicon, magnesium, chlorine, potassium, sodium, sulfur, iodine, and fluorine.

One of the most important facts that we have learned is that from early infancy to death there is a constant stream of food energy entering the bodies of animals. It is in this stream of food that we must seek the source of the chemical elements that enter into the composition of our bodies and those of other animals. These foods always have to be simplified before the cells can take them into the body; this has resulted in there being in each animal special organs to assist in the process of simplification and digestion.

350. Digestive Organs of Man. — Man's digestive organs correspond in their parts to those already studied in the frog and mammal (pages 129 and 177). But each region is more complete and the division of labor reaches a higher development in man. The parts of the digestive system are described under the following headings: the mouth, containing the teeth, tongue, and salivary glands; and the digestive canal, consisting of the throat or pharynx, esophagus, stomach, small and large intestine, and glands such as the liver, pancreas, and gastric (Figure 425) glands.

351. Mouth. — The mouth (Figure 425) is lined with a soft membrane which is kept moist by the saliva. The roof of the mouth is called the *palate*. The front part has plates of bone inside and is

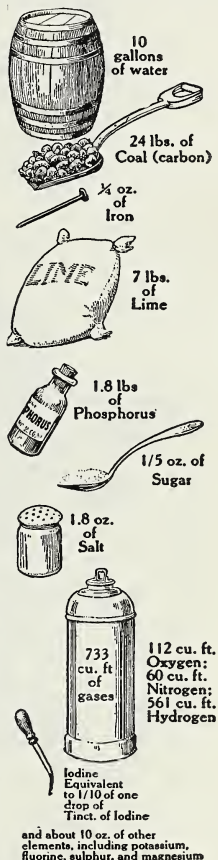
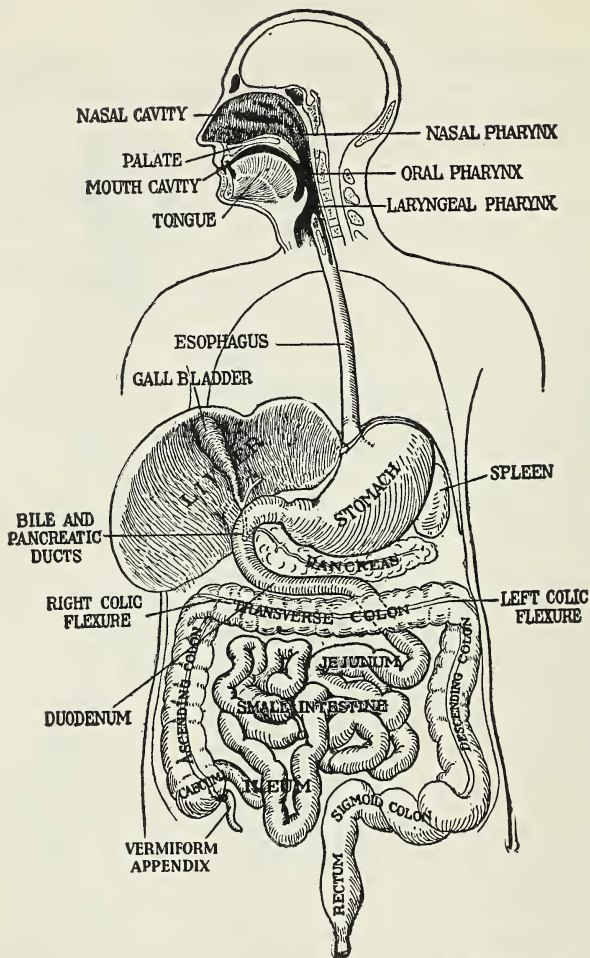


FIGURE 424. CHEMICAL ANALYSIS OF MAN



P. Blakiston's Son & Co.

FIGURE 425. DIGESTIVE SYSTEM OF MAN

therefore called the hard palate. The back part (the soft palate) is a thin sheet of muscle covered by the mucous (mū'kŭs) lining of the mouth. The soft palate separates the mouth from the nasal cavity which is an arrangement that permits sucking.

The tongue is a muscular organ and bears on its upper surface many small fleshy projections called *papillæ*, some of which are fairly large and are arranged on the back of the tongue in the form of a V (Figure 426).

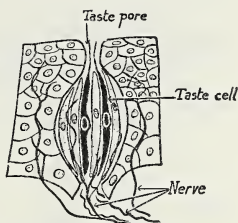


FIGURE 426. TASTE ORGAN IN THE TONGUE

Our power to taste sweet, sour, bitter, and salt, the four fundamental tastes in man, is due mainly to certain nerve cells located on the larger papillæ.

LABORATORY STUDY

Blindfold in turn several members of the class and have each hold his nose while a small amount of some highly flavored food is placed on the tongue. Such common foods as maple sirup, vanilla extract, marmalade, jams, etc., are good for this test. Make a record of each test. This experiment will prove that we do not taste flavors. Remove the hand from the nose and again taste the same substances. This time there will be no difficulty in telling the name of the substance because it has been smelled as well as tasted.

Six glands, three on each side, produce *saliva* that moistens the food in the mouth and assists in digesting it.

Arranged in a semicircle around the center of the mouth

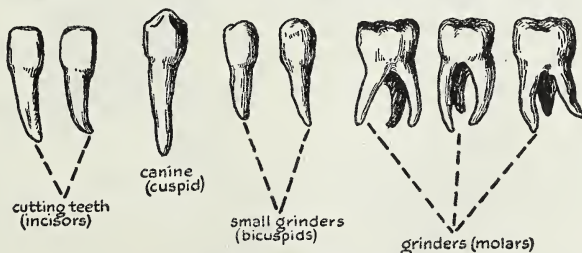


FIGURE 427. KINDS OF TEETH

cavity are the teeth. Each is especially adapted to the kind of work it has to do. In adults there are thirty-two, sixteen in each jaw, belonging to four classes according to shape (Figure 427).

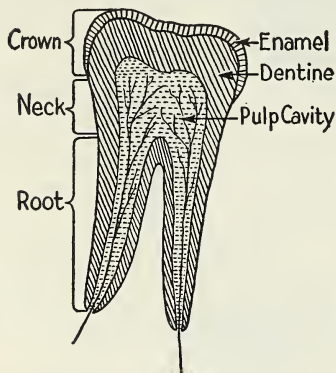


FIGURE 428. VERTICAL SECTION OF A TOOTH

the tooth is covered by an additional layer that is harder than the dentine and is known as the *enamel*.

Care of the Teeth. — Although the teeth are hard, that does not prevent them from decaying if neglected. When the teeth are not cleaned, a substance called *tartar* forms on them, which prevents the bacteria from being rubbed off and sometimes pushes the gums back from the teeth.

The activity of bacteria is hastened by the formation of acids from the particles of food which remain in the mouth after eating. The ac-

Structure of a Tooth. — The general parts of a tooth are the crown, the neck, and the root (Figure 428). In a section of the tooth, you readily make out the *cavity*, sometimes called the pulp cavity, which contains the nerve supply for the tooth as well as blood vessels. This central cavity is immediately surrounded by a bone-like layer known as the *dentine*. The crown of the

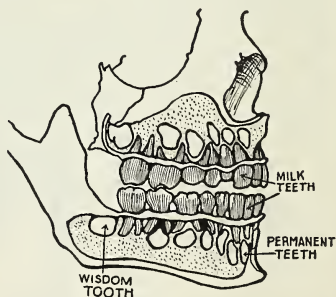


FIGURE 429. MILK TEETH AND PERMANENT TEETH

Milk teeth are the teeth we have as children and which are later replaced by the permanent ones.

tivity of these bacteria results in toothache, a foul breath, and the imperfect chewing of food. The teeth should be brushed morning and night to remove particles of food, particularly sugar, which ferments easily. Poor teeth cannot be made good by brushing, but good teeth can be protected by brushing. At least once a year there should be a visit to a dentist, who will remove those portions of teeth that are decayed and fill cavities, thus preventing further decay. No matter how many other good habits you have you will never enjoy good health unless you chew your food well. Probably more bodily ailments come from hasty eating and the habit of washing down food than from any other cause.

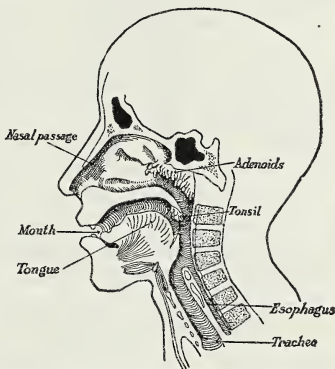


FIGURE 430. UPPER RESPIRATORY TRACT

Only by thorough chewing can we mix the saliva with our food. This secretion aids in digestion and in swallowing. Saliva contains the enzyme¹ *ptyalin* (tī'a-līn), which changes starch into soluble sugars, thus starting the digestion of food before it reaches the stomach.

352. Digestive Canal. — The digestive or alimentary canal of man is a tube about thirty feet long, lined with epithelial tissue and containing connective tissue and two layers of muscles, one of which extends lengthwise and the other in ring-like bands.

The Throat. — Beyond the soft palate is the throat cavity, called the *pharynx*. This is a funnel-shaped cavity, having two openings at its lower end, the front one being the opening into the windpipe which leads to the lungs, and the rear one, the open-

¹ The enzymes (čn'zīmz), or ferments, are the chemical bodies which digest the food. All plants and animals digest their food by means of enzymes.

ing into the esophagus. In the upper part of the pharynx, on each side, is the opening of a *Eustachian* (û-stā'-kĭ-an) tube which passes to the middle ear.



FIGURE 431. PEAR-SHAPED STOMACH

The Esophagus. — The esophagus is a nearly straight tube connecting the mouth with the stomach. It passes through the *diaphragm* (Figure 395), enlarges, and becomes the stomach. As soon as one swallows, control

of the food is lost, and further action becomes involuntary. Two sets of muscles, one extending lengthwise, the other around the esophagus, act together in forcing the food or water into the stomach. This explains why we can drink from a brook when the head is much lower than the stomach.

The Stomach. — In man the stomach is the largest section of the digestive tube; it has a capacity of about three pints. It is usually described as pear-shaped, although there is much variation in its form (Figures 431 and 432). At the point where the esophagus joins the stomach there is a muscular ring, *cardiac* (kār'dī-āk) valve, which ordinarily prevents the food from passing again into the esophagus. In vomiting, this valve becomes relaxed. The opening at the larger and lower end of the stomach is guarded by a similar valve *pyloric* (pĭ-lŏr'ĭk), which serves to retain the food in the stomach until certain digestive changes have taken place.

The Intestine. — The intestine has two parts: a small, much coiled tube about an inch in diameter and about twenty feet long called the *small intestine*; and a large section about five feet long and four inches in diameter, bent in a rough Ω shape and called the *large intestine*. At the junction between these two regions projects a short sac, the *vermiform appendix* (vûr'mĭ-fôrm a-pĕn'dĭks). The disease called *appendi-*



Carleton F. Potter

FIGURE 432. X-RAY PICTURE OF HUMAN STOMACH

This shape is not unusual.

citis (ă-pĕn'dī-sī'tis) affects this organ. The large intestine ends in a special region called the *rectum*. The opening of the rectum to the outside is the *anus* (ă'nūs).

The esophagus, stomach, and intestine are lined with a membrane that is similar to that found in the mouth cavity. This membrane is called the mucous membrane and consists of epithelial tissue. In the esophagus, the mucous membrane is smooth and moist, thus furnishing an easy passage for the food; in the stomach this membrane is in folds except when the stomach is full of food; and in the intestine, it has a velvet-like appearance due to projections called *villi* (Figure 433). The numerous glands of the stomach and intestine are located in the mucous membrane.

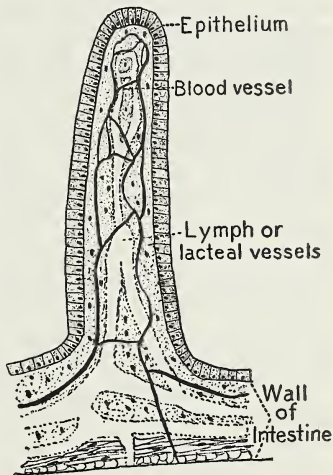


FIGURE 433. DIAGRAM OF A VILLUS OF THE INTESTINE

STUDENT REPORT

Copy the following table and fill it in, comparing the digestive system of man with the digestive systems of the animals studied in Unit II. This will help you to understand better the parts of the digestive system of man and the work that each part does. Do not mark your book.

ANIMAL	ONE CELL	MANY CELLS	NO DIGESTIVE TUBE	DIGESTIVE TUBE	NO WELL-DEFINED DIGESTIVE GLANDS	REQUIRE FOOD?
Paramecium . . .						
Frog						
Man						
etc.						

Glands. — A gland is a group of special cells which secrete a fluid. The glands which produce the digestive fluids are (1) the numerous *gastric* (gas'trĭk) glands found in the lining of the stomach, possibly 4,000,000 in number (Figure 434); (2) the *pancreas*; (3) the *liver*, the largest gland in the body; and (4) numerous *intestinal* glands in the small intestine.

353. Classes of Food. — Food is that which when taken into the body builds up tissue or yields energy. Foods are classified according to the kind of nutrition they supply as *proteins* (prō'tē-ĭnz), *carbohydrates* (kār'bō-hĭ'drāts), *fats*, *mineral salts*, and *vitamins* (vĭ'tā-mĭnz). This classification is made whether we study the foods of a plant, of an animal, or of man. In general the proteins and minerals are necessary for the growth and the repair of the body; the carbohydrates and fats furnish heat to keep the body warm and energy for muscular work; the vitamins are body regulators. The unused fat is stored up as fatty tissue.

All classes of nutrients (§ 22) are found in the various foods obtained from plants. Some, like honey, are nearly pure carbohydrate, while the English walnut contains, in addition to fat, a large quantity of plant protein. Animal foods furnish only proteins and fats. In primitive times man had a coarse restricted diet and led an active out-of-door life. Today man spends much of his time indoors and lives on a mixed and well-cooked diet. The question of how much to eat is a modern problem, and on its solution depend our health, length of life, and energy for work.

Food as purchased contains	Edible portion <i>e.g.</i> , flesh of meat, yolk and white of eggs, wheat, flour, etc.	Nutrients	Proteins
	Refuse <i>e.g.</i> , bones, entrails, shells, cores, etc.		Fats
			Carbohydrates
			Mineral matter
			Vitamins

Carbohydrates are made up of carbon, hydrogen, and oxygen. All proteins contain nitrogen in addition to these three. Because carbohydrates contain no nitrogen, they cannot be used to repair tissue.

USES OF NUTRIENTS IN THE BODY

Protein	forms tissue	} All serve as fuel to yield energy in the form of heat and muscular power.
e.g., white (albumen) of eggs, curd, casein (kā'sē-īn) of milk, lean meat, gluten of wheat, etc.		
Fats	are stored as fat	
e.g., fat of meat, butter, olives, nuts, oils of corn and wheat, etc.		
Carbohydrates	are transformed into	}
e.g., sugar, starch, etc. fat		
Mineral matter (ash)	shares in forming bone, assists in digestion, etc.	
e.g., phosphates of lime, potash, soda, found in milk and fresh vegetables		
Vitamins	keep the body healthy and promote the growth of children.	
in milk, eggs, meat, fruit, vegetables, potatoes, and whole grains of wheat, corn, and rice		

354. The Process of Digestion. — Digestion is carried on by mechanical adaptations, such as the teeth and jaws, and the chemical action of the several secretions that transform the food into solutions. This process begins in the mouth. The teeth break up the food and mix it with the fluid of the mouth, the *saliva*, which contains the enzyme *ptyalin* (page 463). During this process, the carbohydrates are changed into soluble sugars. The fluids of the mouth are usually slightly *alkaline* (āl'kā-lin, a chemical term, the opposite to sour or acid), but as soon as the food passes into the stomach it enters an acid (sour) medium, and the digestive action of the saliva is stopped in a short time by the stomach fluid. The sugar and starch undergo no further digestive changes until they reach the intestine.

Into this acid medium of the stomach, the gastric glands (Figure 434) pour out the gastric juice (a digestive fluid), and the enzyme *pepsin* in this juice acts on the proteins so that they can later pass through the walls of the intestine. In the stomach the heat of the body melts some of the fats into oils, but many of the fats used as food remain solid at body temperature and are unchanged in the stomach.

After one or two hours the food passes into the intestine and undergoes further changes in another alkaline medium. Here the pancreatic juice, which is made in the pancreas, comes into contact with the digested and partly digested food, causing three different changes. One is to complete the change of proteins into simpler products; a second is to finish converting starch into glucose; the third is to assist the bile (the digestive juice made in the liver) to digest the fats. The digestion of the food is practically completed in these three regions of the digestive tube, although digestion continues to some extent after the food is passed into the large intestine.

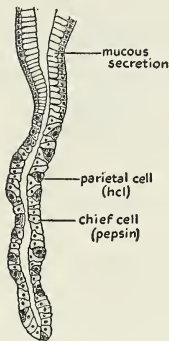


FIGURE 434. GASTRIC GLAND

The lining cells of the inner wall of the stomach project into the tissues of the stomach as minute pockets. The cells shaded in this drawing are the ones that secrete gastric juice.

In addition to the action of the digestive glands, there is the work of bacteria in digestion. While the child is on a milk diet, certain bacteria become adapted to living in the intestine; later, when the diet is more varied, other forms of bacteria are added. The different kinds of bacteria are mostly restricted to the large intestine, where they reach a luxuriant growth. These bacteria feed on the undigested meat and cell walls of plants and such particles as have survived digestion in the stomach and intestine, thus breaking down some of them so that they can be absorbed.

355. Absorption of Food. — After food has been completely digested in the small intestine, it must be absorbed before assimilation is possible. Absorption is the process of taking the digested foods from the alimentary canal into the blood. Practically no food is absorbed in the mouth or esophagus, and but little in the stomach.

Some food is absorbed from the larger intestine, but the small intestine is the main organ of absorption. Its great length and numerous villi and ridges may be regarded as special adaptations

STUDENT REPORT

Where the Food Is Digested

Copy and fill in the following table. Do not mark your book.

PLANT OR ANIMAL	IN THE CELL	IN THE LEAF	PRIMITIVE DIGESTIVE TUBE	STOMACH	MOUTH	DIGESTED BY ENZYMES
Paramecium . . .						
Hydra						
Frog						
Man						
Bean						
Yeast						

for this particular work. The food is absorbed by small folds in the lining of the small intestine. To the naked eye, the folds appear as a covering of minute hairs, villi. Their structure is shown in Figure 433. Water is absorbed chiefly from the large intestine.

The process of osmosis, which was so frequently referred to in Unit I, is the chief factor in the passing of the food into the blood vessels. This process is assisted by the action of the living cells and the movements of the intestine.

The digested proteins and sugars pass directly into blood vessels which lead to the liver through the *portal vein*. In the liver this vein is divided into capillaries — minute



Carleton F. Potter

FIGURE 435. X-RAY PICTURE OF LARGE INTESTINE

The vermiform appendix can be clearly seen.

branches that distribute the blood to the cells of the liver. As the blood thus passes among the liver cells, the larger part of the sugar is changed into *glycogen* (glī'kō-jěn), an animal starch, and stored temporarily in the liver cells. This stored-up starch, glycogen, is given out gradually from the liver as sugar when it is needed by the blood; it thus yields energy to the body. It is also used to furnish energy to the contracting muscles. This work of the liver results in keeping a uniform amount of sugar in the blood.

The fats pass into certain distinct vessels, *lacteals* (lăk'tê-ălz), which in turn open into larger ones. Eventually these vessels unite to form a large duct — the *thoracic* — which empties into one of the veins near the heart. The food is now in the blood stream and is carried to the individual cells of the body. Each cell takes the kind of food which it needs, and by a series of changes, as yet only partly known, makes the food into living protoplasm.

The indigestible part of the food is not absorbed, but continues to move through the small intestine into the large intestine, and on through the rectum. During this progress much moisture is absorbed, especially in the large intestine, which leaves the "undissolved food" harder and harder. The regular removal of the unused part of the food, feces, is of much importance in maintaining health, because the bacteria living in the digestive tract cause the waste material to decay, and the poisonous substances thus formed are injurious when absorbed into the blood.

Foods normally remain in the stomach from one to five hours, and in the small intestine about four hours; they may be from six to twenty-four hours in passing through the large intestine.

356. Milk. — Milk and cream make up about one sixth of the weight of all of the food eaten by the average American family. Wherever conditions are favorable for cattle raising we find the inhabitants using cow's milk; but in those regions of the world where cows do not thrive, such as in the hilly districts of Europe, goat's milk is used. In some parts of India buffalo's milk is common, while in South America the llama furnishes milk.

AVERAGE COMPOSITION OF MILK OF VARIOUS KINDS¹

KIND OF MILK	WATER	PROTEIN			FAT	CARBOHYDRATES (MILK SUGAR)	MINERAL MATTER	FUEL VALUE PER POUND
		Casein	Albumin	Total				
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Calories</i>
Woman	88.3	—	—	1.2	3.3	7.0	0.3	285
Cow	87.0	2.8	0.5	3.3	4.0	5.0	.7	315
Goat	85.7	3.5	1.0	4.5	4.7	4.4	.8	355
Sheep	81.9	—	—	5.3	7.3	4.7	.9	480
Buffalo (Indian) .	82.2	4.3	.5	4.8	7.5	4.8	.8	480
Camel	87.1	3.5	.4	3.9	2.9	5.4	.7	285
Llama	86.6	3.0	.9	3.9	3.2	5.6	.8	305
Reindeer	67.2	8.4	1.5	9.9	17.1	2.8	1.5	930
Mare	90.6	1.3	.8	2.1	1.1	5.9	.4	190
Ass	90.1	.8	1.1	1.9	1.4	6.2	.5	205

Camel's milk in desert countries and mare's milk on the steppes of Russia are as natural to the inhabitants of those places as cow's milk is to us.

Milk is unlike most of our foods because it contains no refuse or indigestible material. Milk is valuable because it contains, first, materials that children need for growth; second, materials that young and old alike need for the repair of the body machinery; and third, materials that all need for fuel, to provide heat and the energy necessary for work. Since milk is especially



FIGURE 436. "MORE PLEASE!"

It is very desirable to develop a taste for milk in children.

¹ From U. S. Department of Agriculture, Farmers' Bulletin No. 1359.

valuable for the variety of its nutrients, nutrition experts recommend that every child have a quart of milk a day and that an adult take at least a pint a day. We should not make the mistake, however, of thinking that milk can serve as the only food for a grown person or even for a child after the nursing age. Iron also is needed in greater abundance than is furnished by milk. Other foods, therefore, are necessary to supplement milk.

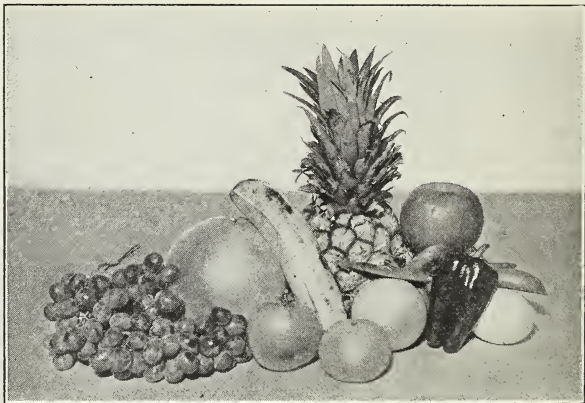


FIGURE 437. FRESH FRUITS

Why should these be included in your diet?

357. Green Vegetables and Fresh Fruit. — Vegetables and fruits are needed to balance the diet. Green vegetables contain a large proportion of mineral matter. For very young children, spinach, asparagus tips, string beans, carrots, and peas, when well cooked and mashed, are highly nutritious. For older children and grown-ups, potatoes, beets, cabbage, onions, and squash are also valuable.

Fresh fruits are especially good for children. There is much truth in the old saying, "An apple a day keeps the doctor away."

358. Meaning of Calorie. — Heat is a form of energy, and one of the reasons for taking food is to keep up the supply of this

energy. The more work a person does the more energy he uses, but even a resting body uses some energy, for the heart beats and the muscles of the chest move. The amount of this form of energy a person uses is measured by a unit of heat named the *Calorie* (kăl'ô-rĭ).¹ A Calorie represents the amount of heat required to raise the temperature of a pint of water about four degrees Fahrenheit. A man in rising from a chair, walking eight feet, and returning to the chair uses about one Calorie of energy.

359. The Proper Amount of Food. — The number of Calories we need depends on our age, sex, size, the region of the world where we live, and our occupation. The following are average amounts:

Girl sixteen years old	2400 Calories
Boy sixteen years old	2700 Calories
Man partly sedentary	3000 Calories
Workman	4000-5000 Calories

360. Uses of the Different Classes of Food. — We know that the Calories must be proportioned among the three main kinds of food: proteins, carbohydrates, and fats. One rule is to eat three times as much fat and six times as much carbohydrate as protein, but this fails to tell the whole story because the right kind of protein and the right kind of fat must be eaten if we are to profit most from combining them in that proportion. A study of our tissues reveals that human beings require many different kinds of protein foods.

Carbohydrates and fats are the foods which supply heat energy and the energy used in contracting muscles, although protein may furnish some of this energy. Carbohydrates supply energy at a low cost when compared with protein. In the summer we can meet our energy need almost entirely with carbohydrates and fats, but in the winter more protein should be added to furnish extra warmth. The sugary carbohydrates are so cheap and tasty

¹ Note that this Calorie should always be spelled with a capital C. This is to distinguish it (the greater Calorie) from the lesser calorie, which is used in physics as the unit of heat. The lesser calorie is the amount of heat that will raise one gram of water one degree centigrade. The greater Calorie is equal to 1000 lesser calories.

that one is apt to overeat of candy, ice cream, and pastry. An excess of these foods in the diet causes a high sugar content of the blood and appears to be related to several intestinal and skin disorders. It has been clearly proved that most of us would have better health if we ate more of the coarser, starchy carbohydrates such as vegetables, fruits, whole-wheat bread, and coarse cereals.

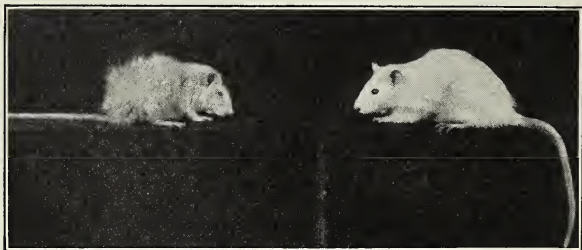


FIGURE 438. THE NECESSITY OF CALCIUM IN THE DIET

A white rat whose food lacked calcium (left) and one whose food contained the right amount of calcium.

Such foods contain more salts, vitamins, and cellulose. Cellulose, which is found in plant cell walls, serves to give a sense of fullness and satisfaction without supplying an excessive number of Calories.

Man like other living things requires a certain amount of minerals in his diet. These are usually spoken of as salts and the principal ones needed are those of iron, calcium, phosphorus, sodium, and potassium. Briefly stated, calcium, sodium, and potassium are necessary for their influence on the heart beat. Iron is used in the hæmoglobin of the blood, phosphorus is present in brain tissue, and calcium aids in the formation of bone. These important mineral foods are found particularly in the skins of fruit and vegetables and the husks of grain. (See Figure 438 for the effect of calcium in the diet.)

361. Vitamins. — The word *vitamin* has been so exploited by advertisers of food products that practically every one has some idea of what it means. The word was coined by a Polish

scientist, Casimir Funk, who believed that there was a special vital substance in foods that was related somehow to the proteins. As we have come to learn more about these mysterious bodies, the word *vitamin* has ceased to have its first meaning, but is retained, because no better term has been suggested to take its place. So



FIGURE 439. THE NECESSITY OF VITAMINS IN THE DIET

These two chickens are of the same age. The one at the left had plenty of food lacking in vitamins; the one at the right had vitamins in addition.

for the present we shall use the expressions vitamin A, vitamin B, vitamin C, vitamin D, vitamin E, and P. P. for the six best-known vitamins.

These vitamins are found in our regular diet as the following indicates, some foods containing more than one.

Vitamin A (also termed fat-soluble A) is present in milk, butter, yolk of eggs, liver, green leaves, whole wheat, carrots, etc. When this vitamin is absent, certain eye diseases, stunted growth, and weakness of lungs develop. Milk and the green leaves of plants are the protective foods.

Vitamin B (also known as water-soluble B) is present in yeast, milk, fruits, and the outer coats of grains. This vitamin is very

little affected by heat. The usual foods contain more of this vitamin than we require. The lack of it in our diet causes the disease called beriberi, a nervous disturbance, and a derangement of the digestion. Vitamin B is probably a mixture of several vitamins.

Vitamin C (also water-soluble C) is present in onions, lemons, oranges, raspberries, apples, tomatoes, carrots, lettuce, and cabbages. It is most abundant in oranges and tomatoes. This vitamin is easily destroyed by heat. When it is absent, scurvy develops. Look up the difficulties that sailors used to have when they made long voyages and the dietary difficulties of the American army during the Revolutionary war.

Vitamin D is present in yolk of eggs, cod-liver oil, and some foods that have been exposed to the sunshine; it prevents rickets.

Vitamin E is found in unpolished (brown) rice, milk, lettuce, yolk of eggs, germs of whole wheat. This vitamin is necessary for the production of eggs and sperms in animals.

Vitamin P. P., or pellagra prevention, is present in yeast and fresh milk and meat.

362. Food Groups. — In our everyday life, we do not deal with chemical groups of foods, but with nature's products which contain proteins, water, and indigestible material in varying proportions.

Here is a safe rule¹ to follow in deciding what foods to eat. Use these foods each day:

1. Milk — One quart for each child; at least a pint for each adult.
2. Vegetables — At least two besides potatoes. A green, leafy vegetable four or five times a week.
3. Potatoes — At least once a day.
4. Fruits — Two servings, one of which should be fresh and uncooked. More may be used.
5. Cereal products — Cereal breakfast foods; breadstuffs. Use a whole cereal product at least twice a day.
6. Meat, egg, fish, poultry, cheese — At least once a day.
7. Butter, lard, oils, or other fats — For bread and cooking.
8. Sugar and other sweets — In small amounts.

¹ From Volume 21, Number 6 of the Bulletin of the Agricultural Extension Service, Ohio State University, Columbus, Ohio.



JOSEPH GOLDBERGER (1874-1929) was born in Austria-Hungary. When he was six years old, he came to the United States with his parents. In 1895 he graduated from the Medical College of New York University. Shortly after this date, he entered the United States Public Health Service, where he remained until his death.

Dr. Goldberger's greatest contribution to science and to humanity was the discovery of the cause, cure, and prevention of pellagra.

Pellagra is caused by the lack of fresh proteins in the diet. We can cure this malady by adding milk and meat to the diet, and we can prevent it entirely by eating these foods regularly.

The persistence of this great benefactor to mankind in searching for the cause of this mysterious malady, and the numerous experiments which he tried on himself to prove that pellagra is not a germ disease, should serve to inspire any boy who aims to be of service to his generation. The splendid assistance which Mrs. Goldberger gave by sharing the dangerous experiments will make her name almost as well known as his.



We have already learned that water does not furnish energy to living things, yet it is absolutely essential to life. About two thirds of the weight of man's body is water, and all of his food contains water. Man would die of thirst long before he would die of starvation. Water assists in digestion, assimilation, excretion, and heat regulation. Water should be taken between meals, rather than with meals, at least in large quantities.

363. Buying Food. — If a family's income is small, the money which is spent for food must be carefully distributed among the food groups. It is not economical to spend more than is necessary for one group, however cheap the food of that group may be, if such expenditure leads to the neglect of another group. Foods of the different groups should be bought in the relative amounts in which they are needed by the body. (Home and Farm Bureaus and similar organizations will furnish advice in buying weekly and economically.)

364. National Food Bill. — How much food does a nation consisting of a million or a hundred million people need each year? Where does their food come from and does it vary from year to year? How much food should be sent to a nation during a famine? We did not have a satisfactory answer to these questions until Dr. Raymond Pearl¹ made a special study of the annual



FIGURE 440. BUYING FOOD

Fresh fruit and vegetables should be a part of our diet.

¹ Proceedings of the American Philosophical Society, volume LVIII, November 3, 1919.

GROUP	AVERAGE FOR SIX YEARS			FOR ONE YEAR		
	Absolute Consumption of Protein (Metric Tons)	Percentage Consumption	Cumulated Per Cent	Absolute Consumption of Protein (Metric Tons)	Percentage Consumption	Cumulated Per Cent
Grains	1,316,140	36.01	36.01	1,303,348	34.44	34.44
Meats	964,117	26.38	62.39	945,277	24.98	59.42
Dairy products	744,784	20.38	82.77	788,969	20.85	80.27
Poultry and eggs	246,178	6.74	89.51	285,413	7.54	87.81
Vegetables	214,404	5.87	95.38	248,772	6.57	94.38
Fish	84,852	2.32	97.70	102,022	2.69	97.07
Oils and nuts	57,839	1.58	99.28	85,021	2.25	99.32
Fruits	24,965	.69	99.97	23,621	.62	99.94
Oleomargarine	838	.02	99.99	1,808	.05	99.99
Sugars	455	.01	100.00	439	.01	100.00
Total	3,654,572	100.00	—	3,784,690	100.00	—

food consumption of the American people. One of his tables is given above in order that you may have a general idea of the wide significance of the study of foods.

In the first line, the figures 36.01% after *Grains* means that foods made of grains constituted 36.01% of the total amount eaten. In the next column, the figure 62.39% after *Meats* indicates that grains and meats together made up 62.39% of our diet, and so on until 100% is reached. This is a table of the average annual protein consumption for a six-year period and of the consumption for one year. This will give you an idea of the source of the more important proteins.

The development and invention of farm machinery during the past hundred years has had an important influence in the production of our food. We must look to this phase of our civilization to greatly reduce manual labor and contribute to food surplus. Before the invention of farm machinery, man spent nearly all of his time in producing his food and other necessities, and shortage of food and even famine were common. Now his granaries are overflowing.

Notwithstanding the great advances that have been made in helping one man to do the work of ten, twenty, or even fifty men, all food still has to be grown and there may be severe shortage of food in large areas when the season is not favorable for standard crops.

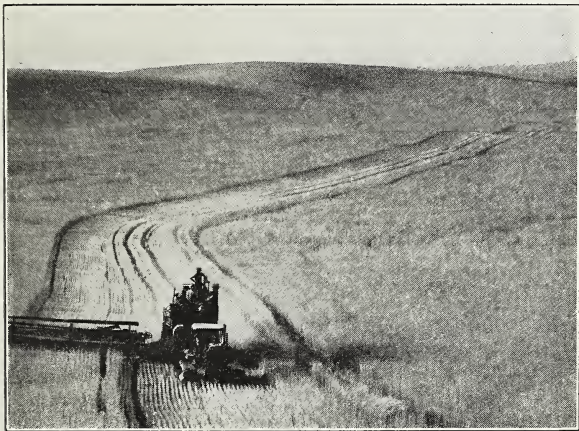


FIGURE 441. HARVESTING

This harvester is a tremendous improvement over the old-time hand instrument.

365. Adulteration of Foods. — Foods are adulterated either by subtracting some of the nutritious parts and substituting less valuable parts, or by adding materials which cannot act as a food.

In white flour the coating of the wheat kernel which contains essential mineral salts and roughage has been removed. This greatly reduces the food value of the flour.

Milk formerly was much adulterated. This adulteration was accomplished by adding water to make the milk go farther when being measured out, and adding *formalin* (fôr'má-lín) to make it keep sweet.

For a time many of the cereals were adulterated with sawdust or peanut shucks. It would require a long description to enumer-

ate all the foods that have been found by the Department of Agriculture to be unsatisfactory for food.

Pure Food Laws. — The Food and Drugs Act passed by the United States Congress on June 30, 1906, requires of manufacturers of foods and drugs that a definite statement be made as to their composition. A number of regulations and rules have been issued from time to time.

The Food and Drugs Act established standards for meats, meat extracts, milk, cream, butter, cheese, ice cream, grains, meals, flour, fruits, vegetables, flavoring extracts, of which there are twenty-four, tea, coffee, cocoa, vinegar, and salt. Before its adoption manufacturers were not required to reach any standard in their products.

SUMMARY

We have noted that man's superiority to animals rests largely on his methods of movement, power of speech, and ability to subsist on a widely varied diet. Man possesses digestive organs that are highly specialized, but he has to rely on rather simple epithelial cells that line the alimentary canal to transform the many different kinds of food eaten so that they can be absorbed. The chemical nature of digestion is the same as in other animals.

The alimentary canal consists of the mouth where some of the starch is changed into sugars, the esophagus for the passage of the food into the stomach where some of the proteins are digested, and the large and small intestine. It is in the small intestine that the major part of digestion takes place. Food is absorbed in both the small and the large intestine.

The teeth play an important part in tearing and crushing our food, while saliva mixes with it and acts on some of the carbohydrates. It is important that the teeth be well cared for.

Most animals keep the body going by eating either flesh or plants exclusively. Man depends upon both. This gives him an advantage over other animals because he can secure adequate nourishment from a large variety of foods. Man, then, is similar to all other living things, in deriving his energy to move, grow, and repair tissue from the food eaten. These foods fall into three classes, proteins, fats, and carbohydrates. Water, vitamins, and minerals are necessary for health.

All of these foods fundamentally depend on the activity of green plants as they manufacture food out of the raw or unusable compounds, water and carbon dioxide. These foods are digested before they can be absorbed into the blood. The blood carries the absorbed food to all the cells of the body.

The fact that man cannot live without food has made it imperative that he be protected from food adulterations which are harmful to him. It is a very rare patented preparation that has a greater food value than the regular foods of our diet.

QUESTIONS

What is digestion? What is absorption? How are the cells of the body fed? What are the several organs of the digestive system? Which ones are larger than corresponding organs in the frog's digestive system? What is the work of the teeth? Where are proteins digested? What is an enzyme? What is absorption?

Define foods. How many kinds are there? Describe them. How do they form in nature? Can man make food out of the raw compounds? What living things can? What is the value of proteins? of carbohydrates? What is a Calorie? How can the supply of food be increased?

SPECIAL TOPICS FOR DISCUSSION

1. Compare the digestive canals of frog and man.
2. How many kinds of taste do you have?
3. Compare the use of the teeth in man, dog, horse, snake, and fish.
4. What are good social conditions for enjoying a meal?
5. What are bad social conditions for eating?
6. Classify the foods that you have eaten for breakfast, lunch, and dinner.
7. Can we rely on our tastes in the selection of our foods?
8. Where do you get your milk and water?
9. What are some of the things that you must consider in securing the proper amount of food?
10. Why are vitamins essential in nutrition?
11. What is the importance of knowing the nation's food bill?
12. What has the United States government done to protect your foods?
13. What does cooking do to foods?

REFERENCES

See list of books on page 505.

CHAPTER XXXIII

THE REGULATING MECHANISMS

The brain is the citadel of the senses.

— PLINY

366. Introduction. — No one knows just how many cells are present in one's body, but the important fact is that most of the time they do their work in a harmonious manner and we are not even aware of their activity. The working of the vast number of cells in the body of man constitutes the most complex structure of which we have any knowledge.

Today we group the regulating mechanisms under (a) the nervous system and (b) the chemical regulators. We are well aware that we could not have any feeling or hearing without certain special organs; nor could we sense pain or see these words without a brain. A great deal has been written during the past fifteen years about our chemical regulators. We know that certain cells manufacture products that are discharged into the blood and by the blood carried to all parts of the body, but we do not know in what fashion the cells are influenced by these products.

367. The Nervous System. — The nervous system of man consists of the same general parts as the nervous system of the frog. (See page 145.) There are a brain and a spinal cord, from which nerves extend to the special senses, the muscles, the heart, and the stomach.



FIGURE 442. NERVE CELLS

These were stained to show the nuclei and the minute parts.

When the brain of man is compared with that of the frog, it is obvious that the cerebrum of man is proportionately larger.

368. Nerve Cells or Neurons. — The nervous system consists of many hundred thousands of nerve cells or neurons which differ from all other cells in having more parts and branches (Figures 442 and 443). Examination shows that a nerve cell has a prominent nucleus surrounded by cytoplasm, which grows out into a number of branches called *fibers*. The shorter branches divide and form, with the branches from the neighboring nerve cells, a mass of tangled fibers. There is usually one longer fiber, perhaps several feet long, which ends either in the skin, in some muscle, or in the spinal cord or brain. When this long fiber reaches the muscle or skin, it divides into several fine branches. All these branches belong to the cell, so in this connection the word *neuron* includes all the branches, the nucleus, and the cytoplasm. *The neuron is the unit of the nervous system.*



FIGURE 443. NERVE CELLS WITH BRANCHES

These were stained with a silver compound, which blackened all the parts.

369. Specialization of the Nerves. — The nerve fibers which have the same work to do connect with one definite region in the brain. A student of the nerves can tell the route which the impulse arising from feeling a pencil must travel before reaching that part of the brain where it is interpreted as a pencil. When we see the pencil, the route over which the sight impulse of the object travels is not the same as that of the feeling impulse. The nerve cells which interpret the impulse arising from feeling the pencil are probably not the same cells that interpret the impulse arising from seeing the pencil. The spinal cord and brain are made up of many special nerve pathways ending in nerve cells that interpret impulses.

The nerves which connect the central nervous system, that is, brain and spinal cord, with all parts of the body consist of many long nerve fibers. Each of these nerves looks like a small white thread and is covered with a thick, fatty sheath (medullary sheath). In the living animal, this fatty sheath is also white, and the nerve fibers so covered are found to occupy a certain part of the spinal cord and brain. Thus, we get the name *white substance*. Other of the nerve fibers and cell bodies are not covered with a sheath and have a gray appearance. Thus we also have the term *gray substance* in connection with the nervous system.

The Central Nervous System. — The nerves carrying impulses of feeling from the hand end in the spinal cord, and those enabling us to move the fingers arise in the same structure. Nerves in the head arise from a larger nerve mass at the upper end of the spinal cord, the brain. The brain is divided into the following parts: *cerebrum*, the most anterior; the *mid-brain*, to which the optic nerves are joined; the *cerebellum*; and the *medulla oblongata*, to which the nerves of hearing and tasting and the facial nerves belong.

The cerebrum of man shows a greater development than the cerebrum of any other animal. Its great size when contrasted with the other regions of the brain and the vast number of nerve cells found in it enable us to understand why this is the most important region of the brain. It regulates all our nervous activities. The cerebellum gives tone and vigor to the contraction of the muscles and helps us to know when we are properly balanced and is hence known as the equilibration center. The remaining parts of the brain give off and receive nerves and transmit nerve impulses to the cerebrum and cerebellum.

Thus each part of the nervous system has a definite function, and is adjusted to its environment by means of the different senses. These we shall study more in detail.

The Sympathetic Nervous System. — This is made up of a double chain of *ganglia* which are connected with one another by nerves and with the central system by fibers. From these ganglia many fibers run to the blood vessels, to the heart, and to the organs of

the alimentary canal. When people die of shock, death is caused by the serious disturbance of the sympathetic system.

370. Development of the Nervous System. — During the early period of growth, the nerve cells send out processes which become nerve fibers, so that at birth the nervous system is ready to go to work. Indeed, nearly all the nerve cells which the human being is ever to use are formed before birth.

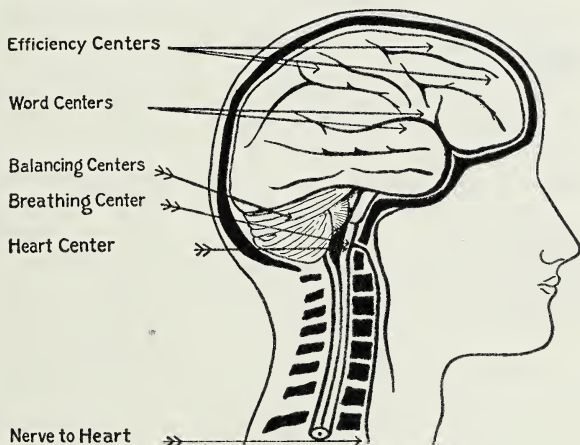


FIGURE 444. CONTROL CENTERS OF THE BRAIN

Long before birth the heart in the embryo (an organism in early stages of development) begins to beat and is under the control of the nervous system. The part of the brain which superintends the heart is located in the medulla, where a special cluster of cells sends out nerve fibers which enter the heart nerve. These nerve cells are called the heart center.

The next nerve center to begin work is the breathing center, located close to the heart center. This does not become active until after birth.

About a year after birth, several more nerve centers become active in the child's brain. These are the ones which help him to

walk. The cerebellum contains nerve centers which play an important part in walking and in learning to balance. The muscles which move the arms and legs are regulated by nerve centers in the cerebrum.

Soon after the child learns to walk, he begins to learn words and talk. The several nerve centers which now become active are

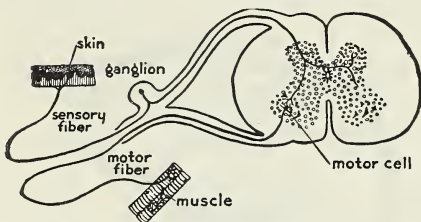


FIGURE 445. DIAGRAM TO SHOW REFLEX ACTION

When the nerves in the skin are affected by a stimulus, they send an impulse to the spinal cord; the impulse passes to a motor cell, which sends an impulse to the muscle. The same impulse from the skin goes to several parts of the spinal cord.

and maturity. The brain becomes a better working organ by making the brain cells do their specific work over and over and over, until each group of cells can be relied upon to do a definite thing.

While the nervous system grows naturally, its training is also important, for it may be said to be the organ of the mind. Habits may be formed, as in the case of the other organs of the body, by the selection and control of certain impulses and sensations.

371. Reflex Action. — Reflex action is the simplest form of nervous activity in man. For example, when the finger is placed on a hot stove and suddenly withdrawn, the following events take place. The heat stimulus¹ affects the nerve endings in the finger and the impulse is carried to the spinal cord. If this were all that occurred, the finger would burn, because this impulse and the nerve fibers over which it travels have no control over

all located in the cerebrum. These are the nerve cells which are necessary in speaking, hearing, reading, and writing words.

All these cells gradually become more active and the different parts of the brain work better as we go through the periods of childhood, youth,

¹ A stimulus is the physical or chemical agent that starts a free nerve-ending or a sense organ to send an impulse to the brain.

the muscles. The removal of the finger is brought about by another set of nerve cells — the cells which have their fibers ending in the muscles of the hand and arm.

Reflex Action in the Frog. — The frog, like man, reacts to certain situations in a definite way. If any one approaches a frog while it is sitting on the edge of a pond, it jumps into the water, stirs up the mud, and then returns to the shallow water near the place where it entered. The frog, in this case, acts as if it, or its ancestors, had learned that this is the best way to escape enemies. Though this series of acts is called a habit, it is really a series of reflex acts which are similar to the reflex action described for man, and require the same nerve structures. Reflex action is similar in all animals.

372. Sleep and Relaxation. — Although some people may be able to do their work with but a few hours of sleep, for the great majority of us cutting short the hours of sleep soon renders us unfit to do our work. Sleep is nature's method of resting the body. The muscles even in their correct use have been under a long strain. The natural waste products caused by the varied activities have accumulated faster than they have been removed and the entire body is fatigued. Some people urge that a change of activity is a rest, but it is only during sleep that the nervous system and muscles are in a reduced form of activity, the most complete form of rest.

Amount of Sleep. — Different amounts of sleep are required in the periods of youth, maturity, and old age. Youth requires more sleep than maturity because two requirements must be met: first, the restoration of the tissues that have been broken down during the day; second, the growth of new tissue as the body is increasing in size during youth. The mature person has only the first requirement to meet. In old age tissues are repaired more slowly and, therefore, more rest is necessary.



FIGURE 446. NERVE ENDING IN A MUSCLE

Eight hours of sleep are about right for most adults, but there are some who need more and some who are better off with less. A simple rule is to ask the question: How do you feel when you get up? Does the world look bright and full of promise? Are you anxious to be "up and doing"? If not, you should get more sleep.

373. Sense Organs. — The special organs of sense in the higher animals are eyes, ears, nose, tongue, and fingers. Each of these organs contains nerves or cells specialized to respond to a certain definite kind of stimulus. The specialization has made them and also the region of the brain which receives their messages complex in structure. The ear nerve responds to a stimulus of air-waves of a certain length, and we say we hear a sound. Each nerve and the brain cells to which it sends its messages have become so specialized that practically only one kind of reaction takes place. For example, all stimuli acting upon the eye nerves are interpreted as light. The *skin* is a simpler sense organ than the eye or ear, and tells us of pain and touch and of the difference between heat and cold.

Smell and Taste. — These two senses are closely related. The sense of smell is located in the nose, and the organs of smell are minute nerve cells scattered among the regular cells that line the nasal passageway. The olfactory nerve which carries smell impulses to the brain is the shortest nerve in man.

Taste has already been described in connection with the digestive system on page 461.

374. The Eyes. — The parts of the eyes of all vertebrates are arranged in a similar manner. The eyeball is roundish and is located in the eye sockets of the skull, which are termed *orbits*. There are an upper and a lower eyelid, and the remains of a third eyelid in the corner next to the nose. The front of the eye is covered by a transparent membrane, the *cornea* (kôr'ně-ă); the rest of the eye is surrounded by a tough membrane, the *sclerotic coat*, or the white of the eye. The tear glands pour their secretions into the outer corner of the eye. This keeps the surface of the eye moist and clean. This secretion is more than just so much

water, for we know that it contains a very small amount of protein. This protein is the same in the tears of all men, but is different from the protein found in the tears of animals. Within the combined covering of the cornea and *sclera* are a number of structures which take part in receiving rays of light and transmitting nerve impulses to the brain.

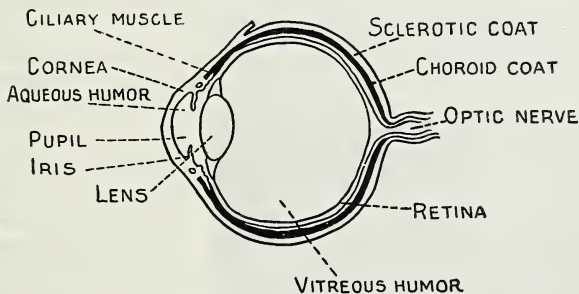


FIGURE 447. DIAGRAM OF EYEBALL

A cross section of the eye shows two more membranes in close relation to the sclerotic coat (Figure 447). The membrane in direct contact on the inside with the sclerotic layer is the *choroid* (kō'roid). The choroid coat is filled with blood vessels and pigment. Through this layer the food in the blood is distributed to the eye. The third layer or coat is the *retina*, which is composed of nerve cells and is nearly transparent.

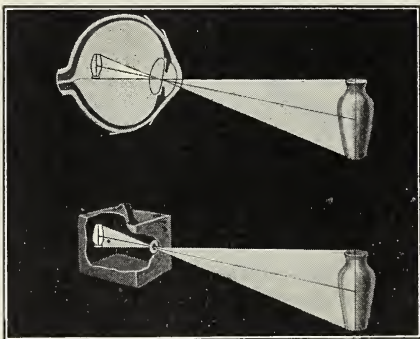
The cornea and these three layers inclose two chambers which are separated by the *lens* (Figure 447). In front of the lens a curtain-like membrane, the *iris*, partly covers the lens, except for a round opening in the center, which is called the *pupil*. The color of the eye, gray, hazel, blue, or brown, is due to the presence of pigment in the iris. The small front chamber is filled with a transparent fluid which is composed principally of water and is known as the *aqueous* (ā'kwē-ūs) *humor*. The large back chamber is filled with a thin, transparent, jelly-like fluid, the *vitreous* (vīt'rē-ūs) *humor*.

375. Mechanism of the Eye. — The eye is constructed to “take pictures,” and in fact has exact counterparts in the camera. It is inclosed in a bony socket, as we have seen, which is similar to the case of the camera. The eyelids correspond to the shutter. The iris regulates the amount of light admitted to the eye just as the diaphragm does in the camera. Most interesting of all is the lens corresponding to the camera’s lens, and the retina corresponding to the film or plate of the camera.

The eye is a marvelous mechanism. The clearness of a picture in the camera or the eye depends upon the proper focus of the lens.

Whereas the camera must be focused by moving the lens backward or forward, the lens of the eye is automatically adjusted by little muscles which instantly accommodate the eye to objects at any distance.

When we see any object, such as a jar, two main processes take place. First, the retina receives the



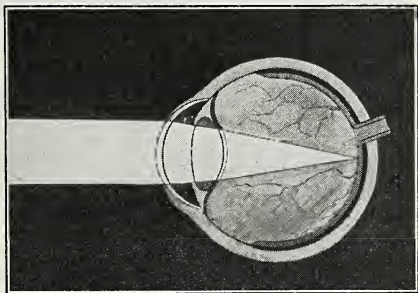
American Optical Company

FIGURE 448. EYE AND CAMERA COMPARED

picture, or rather image, of the jar, this image being composed of light rays reflected by the jar. In physics we learn that the rays of light travel in straight lines. (This fact explains why we cannot see around a corner.) When the rays of light are made to pass through a glass lens, the rays which pass through the thin edges of the lens are bent and do not travel to the same place they would have reached had they not passed through the lens. In the same way light rays from an object pass through the lenses in our eyes and are bent. This results in the image of the object, the jar in this instance, being inverted on the retina.

Second, the light rays from the jar stimulate the nerve cells in the retina, and this impulse, after being carried to the brain, is interpreted to us as a jar, though we do not know how the impulses, resulting from stimuli, travel on nerves.

The inverted image on the retina is due to the shape of the lens. When the stimulus reaches the living cells of the retina and the impulse is passed by them to the optic nerve and the brain, a series of changes takes place in these living cells. There is no evidence as to how an inverted or upright picture passes through these living cells in the retina and brain. We do know that we have to learn the meaning of all stimuli.



American Optical Company

FIGURE 449. PERFECT VISION

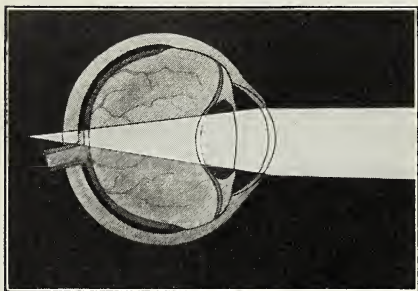
For example, a baby reaches for things far beyond the length of its arms and it is only after many trials that it eventually acquires precision in reaching for an object. It is probable that each one of us passed through a similar stage of learning to interpret the impulses that arose from light. In coming to understand light stimuli, the sense of touch was of great assistance. Try to explain how this would be so.

The camera's film is limited to one clear impression that must be laboriously developed and printed by chemical processes. The capacity of the retina to take pictures, however, is almost infinite. In the very instant that an object is registered on the retina, the image is dissipated and flashed to the brain and room is provided for another picture.

How wonderful it is that the eye, though only one inch in length, develops its own pictures and perceives objects at various distances and in various positions — without approaching or mov-

ing away and without changing the position of the head or of the object. Such delicate coördination is a priceless possession.

As the lens of a normal eye is convex, waves of light are



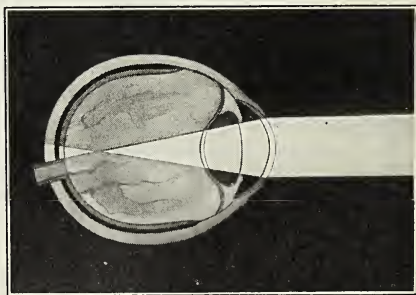
American Optical Company

FIGURE 450. FAR-SIGHTED EYE

converged as they pass through. For perfect vision, eye lenses must refract light rays so that they focus correctly upon the retina without conscious effort, as shown in Figure 449.

known as far-sightedness. People having this defect can see clearly and without effort when an object is far away. Near objects are indistinct because their image is focused behind the retina, as shown in Figure 450. Reading or close office work is most fatiguing to far-sighted people.

When the eyeball is too long, what is known as near-sightedness occurs. People having this defect can see clearly only when the object is near. Distant objects are indistinct because their image is focused in front of the retina, as shown in Figure 451.



American Optical Company

FIGURE 451. NEAR-SIGHTED EYE

Both far-sight and near-sight are defects which can be corrected readily by glasses with lenses of the proper curvature and power.

Astigmatism is a complicated form of defective vision. People having this defect see objects with unequal clearness in different directions. The correction of astigmatism is relatively simple by means of glasses with special lenses.

377. Care of the Eyes. — In reading, the light should be sufficient and steady and should come over the shoulder. The eyes, like the rest of the body, get tired and need to be rested. They give us the best service when the entire body is in a healthy condition.

Injuries to the Eye. — Foreign bodies are frequently blown into the eye. These often have sharp corners that scratch the cornea. If medical assistance is not available, a clean handkerchief moistened with water may be used. When anything like a splinter of metal penetrates the eye, it should be removed by a physician as soon as possible. It is important to remember that a serious injury to one eye often extends to the other eye; great care should be taken whenever an eye is injured.

378. The Ear. — The ear receives stimuli which are interpreted by the brain as sounds. The ear of man consists of the outer, middle, and inner ear. The first two carry the stimuli to the third, where they are received by nerve cells and carried to the brain.

The diagram of the ear (Figure 452) shows the several parts and their relations. The outer ear leads to the *tympanic* (tīm-păn'ik) cavity; the middle ear is in communication with the

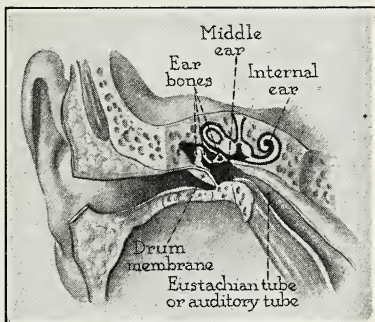


FIGURE 452. SECTION THROUGH THE EAR

The Eustachian tube is split and spread open, making it appear larger in diameter than it really is. What forms a bridge across the air space of the middle ear, connecting the drum membrane with the internal ear?

mouth, and the complex inner ear is partly shown. There is a group of small bones in the middle ear which conduct the sound vibrations to the delicate inner ear. The internal ear receives the various vibrations and transmits them to the brain, where they are explained as sounds.¹

| *Hearing.* — Sound waves strike the ear drum (tympanic membrane), causing the small bones in the middle ear to vibrate. The bones cause the water in the internal ear to move, thus stimulating the nerves of hearing.

| The pressure of air on both sides of the ear drum is normally the same. This is due to the entrance into the middle ear of air from the mouth, through the *Eustachian tube*. This tube is a trifle more than an inch long. When it becomes closed, partial deafness results.

Defects in hearing may be caused by blows upon the ears, by the accumulation of wax in the ears, and by sore throat.

Care of the Ears. — Next to our eyes the ears are our best sense organs, and we should know how to take care of them. There are so many harmful things that can easily be done, that one authority has said that the best treatment to give the ear is "absent treatment." He means to let the ear alone except to keep it clean. To do this, the proper use of a wash cloth is all that is necessary. The wax in the ear normally moves outward and the cloth on the end of the finger will keep the ear sufficiently clean.

It is important to heed the old saying, "Never pick your ear with anything smaller than your elbow." Digging the ear with toothpicks, hairpins, and other hard and pointed instruments is often the cause of irritation that is followed by inflammation. If your ears are not comfortable or if you do not hear well, go at once to an ear specialist.

Most of our ear trouble comes from infection in the middle ear, which is connected with the mouth by the *Eustachian tube*.

¹ When certain parts of the ear (semicircular canals) are injured, one has difficulty in standing or in walking erectly. This is because the inner ear serves both as a hearing and as a balancing organ.

When one has a cold and blows his nose very hard, especially if he pinches the nose, the result is often to force some of the germ-laden mucus into the Eustachian tube. Here the germs grow rapidly, causing congestion and inflammation. The different conditions that arise from such infections of the middle ear are the chief causes of deafness.

The ear drum receives the gentle sound waves and transmits them through the bones of the middle ear to the internal ear. If the ear drum is injured, as it can be even by striking the ear with one's hand, it does not vibrate properly.

379. An Old Idea of the Chemical Regulators. — The savage who ate the heart of his slain enemy to increase his own courage represents an idea that is very old. We find that the ancients prescribed that the lung of a fox be eaten by those who were short of breath because the fox is able to run rapidly for a long time. These early beliefs led the medicine men to compound strange mixtures on the principle that certain organs contained the healing principle. Peter of Lisbon in about 1276 published a popular book dealing with the methods of healing and he quotes with approval Gilbert's ointment for gout: Take a frog when neither sun nor moon is shining; cut off its hind legs and wrap them in deer skin; apply the right to the right foot and the left to the left foot of the gouty person, and without doubt he will be healed.

380. The New Idea. — Each organ in our body is composed of many cells and each cell contributes something to the work which every organ does for us. If the organ is a gland, it may manufacture either too much or too little of its product and the changes that follow, if correctly understood, are traced to the cells. The new idea is to restore these cells to their normal activity.

You see that modern science retains that portion of the old idea that each organ has a definite contribution to make to our normal life, but we have discovered that the problem of restoring the over-active or under-active cells to their natural speed of making products for our body is one that only the trained physician should undertake to solve.

381. Glands. — The glands in our bodies are of two general classes: (1) those that discharge their products through ducts such as the salivary, liver, sweat, ovaries, testes, and many others; and (2) the several glands that have no ducts and whose products escape directly into the blood, as in the case of the thyroid and adrenal. It was natural to place all of these without ducts together and name them the ductless glands, but as scientists learned more about the activity of each separate group of cells in glands, it was clear that there were glands containing both cells that discharged their products through ducts and cells that emptied theirs directly into the blood. The pancreas which discharges its enzymes through the pancreatic duct into the intestine and its insulin directly into the blood is an example of such a gland.

These double-acting glands forced scientists to describe them not as duct and ductless glands but in terms of their manufactured product. This gave rise to the term *endocrine*, which means "separated within," and it soon became the custom to refer to all of these organs as the endocrines, the substance produced as a *hormone* (hôr'môn), an endocrine, or an internal secretion. There are two types of hormones called *accelerators* and *depressors*, according to whether the secretion increases or retards a particular activity. The main endocrine organs and their products are as follows:

1. *Thyroid*. — This is a gland located on each side of the trachea just below the larynx. The two arms are connected so that it is often described as U-shaped. In comparison with its size, it has many blood vessels that break up into capillaries. The secretion of the thyroid is a hormone called *thyroxin* that passes into the blood through the capillary walls.

Thyroxin contains a large amount of iodine. The chief use of thyroxin is to aid in metabolism. When the thyroid gland becomes enlarged, it is called a goiter.

2. *Parathyroids*. — These are two pairs of very small glands, often imbedded in the thyroids, whose secretion has an intimate relation to the amount of calcium in the blood.

3. *Thymus*. — These two glands are located in the chest cavity near the heart. They develop early in the life of the child and gradually become reduced in size between the ages of eleven and fifteen. They have an important part to play in the normal development of childhood.

4. *Adrenals*. — The term *suprarenals* is also given to these two glands that lie near the upper ends of the kidneys. The well-known product, adrenalin, serves to increase the action of the heart. This product can be made by the chemist and is sold commercially. It is used in surgery. There seems to be some relation between anger, fright, and the quantity of adrenalin in the blood. The increased amount causes the contraction of the involuntary muscles.

5. *Pituitary Body*. — This gland is located on the floor of the brain and consists of three parts. It produces at least two distinct secretions, both of which have a stimulating action : one on growth and the other on the involuntary muscles of certain organs.

6. *Pineal Gland*. — This lies on the dorsal surface of the brain, between the lobes of the cerebrum. The use of its secretion is not well understood.

The following glands have a double function, for they manufacture products that escape by ducts and products that are secreted directly into the blood :

1. *Pancreas*. — It has been known for many years that the disease called diabetes was immediately due to the failure of the body to oxidize properly all of the sugars that were eaten as food. Dr. Banting of the University of Toronto succeeded in 1922 in isolating from the pancreas the specific substance that stimulates the body in such a way that sugar is utilized. This substance is known as *insulin*. Insulin is *not a cure* for diabetes ; it merely relieves the symptoms.

2. *Reproductive Glands*. — These glands produce, in addition to sperms or ova, a secretion which acts on the general appearance and disposition of the individual.

3. *Secretin*. — This is the name of a secretion by the cells that line the intestinal tract. When the digested food of the

stomach, which is acid, comes in contact with these cells, they discharge a hormone into the blood. This hormone is carried in the blood until it reaches the pancreas and possibly other digestive glands. Here it stimulates them to discharge their digestive enzymes.

382. The Endocrine System. — The endocrines form a system of organs within our bodies just as do the parts of the digestive, respiratory, or nervous systems. When we make a microscopic study of the endocrine organs, we usually find certain cells which take from the blood the raw materials that they need in order to manufacture their specific products; for example, the thyroid produces thyroxin and the adrenal, adrenalin.

Each gland combines these raw products which are frequently termed the chemical regulators. All such products are returned directly from the gland into the blood stream from which the cells took the raw products. Each of these endocrine products has a specific effect on different parts of our body.

The endocrine system in man and the other vertebrates is one whose vital importance has only recently been understood. The information now available shows that each of these endocrine organs manufactures a different product. The usual amount of these chemical regulators which is present in our bodies may be very small, yet on their presence depends our normal growth and functioning.

When the quantity of endocrine released from any of these organs is more or less than the normal amount, it requires the specially trained expert in this field of medicine to correctly recognize and explain the results.

The question may occur to you, "Can the body get along without the presence of some of these glands?" The answer is "yes," for some, and "no," for others. For example, a person may have the thyroid gland completely removed but not the parathyroids, or he may have part of the adrenal removed but not all of it. If any one of these glands is removed, it becomes necessary for the product normally produced by it to be artificially supplied. It is this study which has proved most fascinating to the investigator.

383. A Scientific Victory. — The first problem that had to be solved was the isolation of a pure extract from each of the endocrine glands. This was followed by a careful chemical study to determine the exact composition of the secretion. It required many experiments and much patient research before even these first steps were taken and there are still several endocrine glands to be studied. The next step was to attempt to manufacture these same products in the chemical laboratory. After a long time success came and the results were heralded as a great scientific victory. Before we could be confident that the new artificial product was satisfactory, it was necessary to inject it into an animal and compare the results with those produced by the naturally produced secretions. As soon as men were able to perfect their experiments, it was found that the artificially manufactured product would take the place of the natural secretion. The importance of this achievement can hardly be overestimated since it has meant that individuals suffering from a lack of these materials can have the abnormal condition at least partially remedied. We now have at our command from the chemical laboratory thyroxine similar to the product of the thyroid gland and adrenalin similar to the natural product of the adrenal gland.

We have really made only a beginning in the scientific study of the endocrine system and we anticipate that a great deal more will be discovered in the next few years. It is becoming more and more evident that these endocrine secretions play a very important part in the normal activity of our bodies such as speeding up the oxidation of food, controlling the storage and the use of sugar in the body, or powerfully stimulating either the voluntary or involuntary muscles. These secretions also have an important effect on the activity of the endocrine glands themselves and this is one of the most difficult phases of the whole story to unravel. Each year more information is obtained which makes this little-known system of ours better understood, and you should be keenly alert to read about the additions that will be made from time to time.

SUMMARY

The organs in man, though extremely complex in their interrelations, work in perfect harmony in a normal healthy individual. By means of them, he can surpass all other animals in planning for the future and in taking advantage of past experiences. His marvelous brain and clearly superior mental endowments permit us to place his nervous system higher than that of all other animals.

The nervous system of all vertebrates consists of a brain and spinal cord with nerves passing to all organs of the body. The brain of man is the most highly developed.

All our movements are controlled by means of a nervous system. Through our sense organs we gain our information of the world.

The nervous system is made up of cells which are highly specialized. Their main work is to transmit and interpret stimuli. The nerves of man are so highly specialized that all stimuli which affect the eye are thought by us to be light stimuli; all stimuli which enter the ear seem to be sounds. The impulse which passes over any of our special sense organs travels over several different nerve cells before it reaches the place in the brain where it is interpreted. The highly specialized nervous system and sense organs grow and are fed just as muscles and skin grow and are fed. There is no special food which we can eat that is used exclusively by the nervous system. When the brain is affected by alcohol, it is the highly developed centers that suffer most.

Special attention should be paid to getting proper rest and relaxation, and the eyes and ears should have particular care.

QUESTIONS

What is the nervous system? Of what parts is it composed? What animals have you studied that have a nervous system? Which ones lack a special nervous system? How does the nervous system grow? Describe the nerve cell. How does it differ from other cells in man? What are special senses? What kind of information do you receive through your eyes? What kind through your ears? Which do you remember? (The well-trained mind remembers equally well the information that comes through the different sense organs.)

SPECIAL TOPICS FOR DISCUSSION

1. In what respects are the cells of the nervous system like those in muscles, bones, the skin, and lungs?
2. In what ways is the nervous system dependent on the other cells of our body?
3. Do the rest of the cells serve the needs of the nerve cells?

4. Does this study of the nervous system help you to understand the meaning of *higher* and *lower* in the animal scale?
5. Does your dog have a mind? Explain.
6. How much can man teach animals?
7. Do we gain our information about trees, water, and sounds in the same way as do animals?
8. How do our sense organs compare with those in animals?
9. Can a full-grown man do more than you can?
10. Red hair is a sign of violent temper.
11. Brains and beauty are rarely found in the same body.
12. A high forehead indicates superior intelligence.

REFERENCES

See list of reference books on page 505.

CHAPTER XXXIV

THE BEGINNING AND THE END

Whatever begins, also ends.

—SENECA

384. The Beginning. — The general plan on which our bodies are built has been in existence for a very long time. From the period when earliest man existed up to the present there have been but minor changes in his body, such as a more erect posture, a different shaped head, or a more supple thumb. No really new structures have been added throughout this long period.

While there is still much to learn about the origin of the race of man, we do have some definite facts about how each of us started our individual lives and that is when a sperm cell united with an egg or ovum. In this respect we resemble all of the higher animals and even the plants (page 264). This union of the sperm with the ovum is fertilization, and can take place either outside or within the body of animals. When it takes place within the body, which is the case with all the higher animals, special organs are usually present in which the young animal is cared for until old enough to be set free.

It takes nine months for the human egg cell to grow into a complete set of human organs such as you have just been studying. We are really nine months old when we are born. Some of the organs begin to work long before others. For example, the heart starts to pump blood to the growing organs several months before birth and is the first organ that takes on the burden of existence, beating continuously as long as life lingers in the body. Blood vessels *absorb* food from the mother, and thus energy for the growing child is always present.

385. Development. — This origin of every human being is a wonderful process. In each normal person hands and feet arise without much variation. But hands and feet are made up of bones, muscles, nerves, blood vessels, and connective tissue each distributed in correct proportions. The same kind of statement can be made for all of the other structures in our bodies. Hundreds of thousands of cells arrange themselves in the plan that always results in a body which we recognize as that of man. When the time comes, as we grow from infancy into youth, that we need certain organs, they are already present.

The fertilized ovum of man nearly always grows into a perfectly normal boy or girl. During this process of growth, each boy or girl takes on a certain color of hair and eyes, the skin is light or dark, and the general proportions of the body indicate that the young child is to be either like the father or mother in appearance or partly like the father and partly like the mother. We have already discussed the subject of heredity (page 376) for animals and plants, and man is no exception. It is too soon to lay down definite laws of heredity for man, but in the main he agrees with other living things in deriving his individual characteristics from his parents and grandparents.

No one can predict which modifications of color, size, or temperament will appear in the child. One child has red hair and another black. One child grows tall and another short, and a similar variation holds true for all of the organs in our bodies.



FIGURE 453. A FAMILY GROUP

What stages of development are represented?

This view of our beginning reveals to us that each of us has one job that no one else can do for us, for everything which we do is influenced to some extent by the peculiarities of our cells. Each one must live his entire life within a body that in certain respects is unlike the body of any other boy or girl that has ever lived.

386. Learning. — If you could recall your efforts as you learned to walk and talk, this phase of your biology would seem very real. Possibly some of you can still recall your struggle to write your name twice alike. Even now some of you find this difficult. These simple and familiar experiences reveal that although each has the same organs and cells, these organs and cells behave in a way that indicates that there are differences in each of us. Thus from the very beginning each has certain problems to solve. By the time we reach the age of twelve or fourteen years, certain cells become active for the first time and their activity results in manufacturing products that stimulate our bodies to grow rapidly and induce other marked changes.

This period in our lives is followed by one in which we try to gain control of our bodies and minds, and we begin to understand our limitations. It is the period of education in high school and college and each one needs to set an objective or goal. As we aim to fit into our civilization, we shall find other problems to solve, and one of the factors in our success will be the degree with which we understand our own individual biology.

When you have passed your examinations and have started in on your chosen work, whether it be the making of a home or developing a profession, again new problems will demand attention and their solution will be partly influenced by your biological equipment. Your parents are busy, as you will be, in working out their tasks and making their bodies contribute to their solution.

387. The End. — In the course of time your body will grow old. We really mean by this expression that certain cells will no longer work so well as they did in middle life. No one can tell you in advance which group of cells will begin to slow up first ;

but when this period is reached, and there is no fixed age limit set for its arrival, other biological problems make their appearance for the first time in our lives and we have to adapt ourselves to the weaknesses of old age.

Finally one or more groups of cells fail entirely to do the tasks which they alone can perform; the work which they have been doing all your life is indispensable, and death follows. Death marks the biological end of all forms of life.

REFERENCES

- Berman, *Food and Character*, Houghton Mifflin Company
Best and Taylor, *The Human Body and Its Functions*, Henry Holt and Company
Blackmar, *History of Human Society*, Charles Scribner's Sons Company (1926)
Burton-Opitz, *An Elementary Manual of Physiology*, W. B. Saunders Company
Cannon, *The Wisdom of the Body*, W. W. Norton and Company
Causey, *Uninvited Guests, a Short Account of the Animals Living On or In Us*, Alfred A. Knopf Company (1932)
Clendenning, *The Human Body*, Garden City Publishing Company
De Kruif, *Men against Death*, Harcourt, Brace Company
Elwyn, *Yourself, the Story of the Human Body*, Howard McCann (1930)
Haggard, *Devils, Drugs and Doctors*, Harper and Brothers
Haggard, *The Science of Health and Disease*, Harper and Brothers
Harvey, *Simple Lessons in Human Anatomy*, American Medical Association
Herrick, *The Thinking Machine*, University of Chicago Press
Hoskins, *The Tides of Life*, W. W. Norton and Company
McCollum, *The Newer Knowledge of Nutrition* (third edition), The Macmillan Company (1925)
Newburgh, *The Exchange of Energy between Man and the Environment*, Charles C. Thomas (1930)
Sigerist, *Man and Medicine*, W. W. Norton and Company (1932)
Smallwood, *Man, the Animal*, The Macmillan Company
Stieglitz, *Chemistry in Medicine*, Chemical Foundation (1928)
Stubbs and Bligh, *Sixty Centuries of Health and Physick*, Paul B. Hoeber, Inc. (1931)
Wells, Huxley and Wells, *The Science of Life*, Doubleday, Doran and Company

CHAPTER XXXV

SOME BIOLOGICAL PROBLEMS THAT MAN TRIES TO SOLVE

Great accomplishments in life are more often due to purposeful activity than to chance. — HURD

388. Introduction. — We shall turn our attention now from the analysis of the work of the several organs of man to some of the broader scientific problems that are of interest to each one of us. In our analysis we shall stress the biological features, although these cannot be separated entirely from those which are social and economic.



Courtesy E. W. Gudger

FIGURE 454. RAINING OF FISHES

This is a copy of a drawing made in 1567 to show the common belief at that time that fishes rained from the sky. Is this true?

389. Keeping Well. — Good health consists in keeping well or taking the necessary steps to recover from injury or disease. From the earliest records of man, strange beliefs have been held about what is good health and what the causes of sickness are.

The following account of pestilence which is expressed in modern English is a good example. Andrew Borde in a book, *Doctor of Phiscke*, 1547, wrote that pestilence comes either by the punishment of God or else of a corrupt and contagious air, and one man infected with this sickness may infect many men. This sickness may come also with the stench of dirty streets, of standing water, of stinking puddles, shedding of man's blood, of

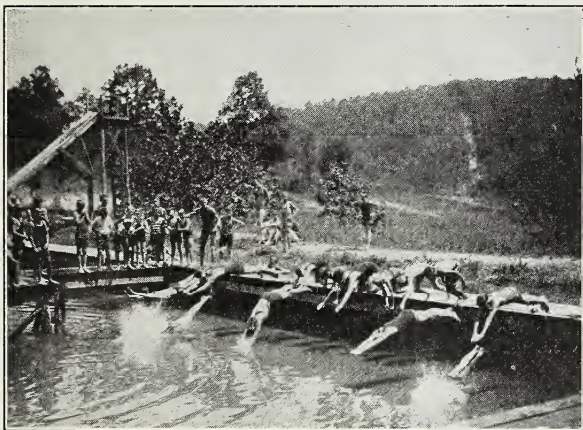


FIGURE 455. BUILDING STRONG BODIES
Above : Learning about and enjoying nature.
Below : Healthy exercise for growing boys.

dead bodies unburied or of a great number of bodies being in a little or small room.¹

The remedy which Dr. Borde prescribes is equally interesting: "The chief remedy that I know, is for every man to submit himself to God, and then to amend our living, and flee far from infectious places. . . . Then to use a good diet in eating and drinking and use perfumes in your chambers and houses, go not abroad in the open air, late in the night, nor rise early in the



FIGURE 456. HEALTH, A VALUABLE ASSET

morning; let the sun have dominion over the ground to waste and consume all contagious mists and airs, then arise and serve God which doth give health to all men."

Science has moved a long way from the ideas of Dr. Borde, but those who are not familiar with the discoveries in biology in the field that deals with the causes of disease may still have equally crude beliefs.

There are three general factors that enter into good health. The first, and in some ways the most important, is the kind of

¹ Stubbs and Bligh, *Sixty Centuries of Health and Physick*. Hoeber, pub., page 114.

body that we have inherited from our parents; the second is the care which we received during the first few years; and the third, our own ideal of good health. Too many of us are satisfied with a standard of health that falls far short of that vigorous health that should be our ideal. One of the best satisfactions that you will ever get in life will be trying to measure up to your ideals. What is your ideal of good health? This is ours.¹

1. To be able to carry out with zest our regular work without undue fatigue.

2. To be able to enjoy three well-balanced meals without digestive disturbances.

3. To be able to sleep soundly eight hours a night.

4. To be able to enjoy one hour of vigorous physical exercise daily without feeling undue fatigue.

5. To be able to enjoy the society of others for at least one hour each day without irritability, boredom, or undue self-consciousness.

6. To have some special hobby, *i.e.*, an intellectual interest in something that is not connected with our regular work. In our youth this took the form of collecting specimens and pets; now we turn for our hobby fun to literature, photography, and games.

7. To be able to undertake the day's work confident, optimistic, enthusiastic, "expecting success and attaining it with reasonable frequency."

390. Economic Importance of Health. — Under ordinary circumstances about three per cent of the people of this country are sick. It is difficult to measure properly the loss this causes to the community. When a wage earner is sick and cannot work, the loss of money is the amount he might have earned. The Committee on the Costs of Medical Care has assembled facts which we have difficulty in comprehending because of their magnitude. There are 1,100,000 persons engaged in some phase of medical service with a total annual expenditure for such services of \$3,647,000,000. More than \$3,000,000,000 is invested in hospitals alone. The annual number of deaths due to communicable disease in the United States is greater than the number of Americans who were killed in the World War. But \$360,000,000 go for the purchase of "patent medicines" and

¹ Modified from *College Textbook of Hygiene*, Smiley and Gould, page 2.

\$125,000,000 for the services of cultists and irregular practitioners who have never studied the human body.

While some sickness is due to diseases over which science has not yet gained control, much of it is caused by animals and plants living within our bodies as parasites. Such diseases can be prevented by vigilance, cleanliness, and wholesome living. Before we can have a scientific basis for curing disease, we must understand how diseases are caused. We have made progress, as the following classification reveals.

391. Classification of Diseases. — Diseases may be grouped under four headings: (1) inherited diseases, *i.e.*, those transmitted from parent to child, as, rarely, insanity; (2) diseases caused by such poisons as lead,

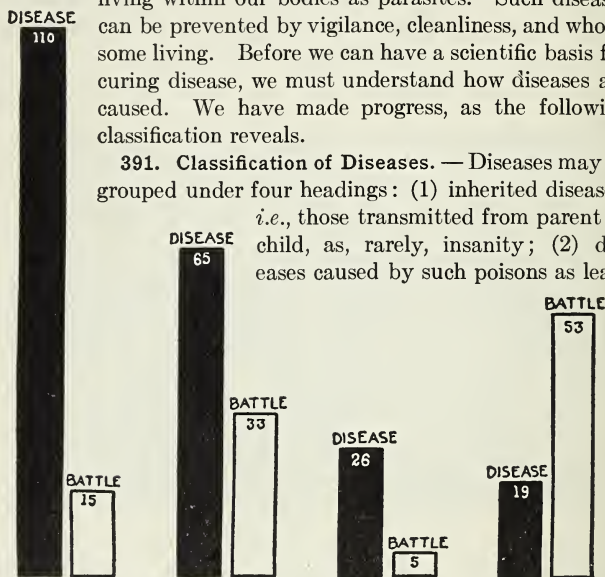


FIGURE 457. WHAT SANITATION CAN DO, A TRIUMPH OF BIOLOGY

The number of deaths by disease and by battle among a thousand soldiers of the United States each year in the Mexican, Civil, Spanish, and World wars.

arsenic, mercury, phosphorus, opium, cocaine, alcohol, and the like; (3) diseases in which certain tissues take on an abnormal growth, as in tumors and cancers; and (4) diseases caused directly or indirectly by some definite living plant or animal, also called *biological diseases* because the source or cause is in every instance some definite living plant or animal. In our ordinary daily speech we often speak of these as "germ" diseases.

392. Biological Diseases. — The rattlesnake secretes a poison which is forced through fangs (Figure 142) into the blood of its prey. This poison affects the heart and may result in death. One of the common and beautiful mushrooms (Figure 322) produces a similar poison which is not destroyed by cooking. If this particular mushroom is eaten, death is almost certain to follow in from twenty-four to forty-eight hours. In both these cases the animal or plant is large enough to be seen and easily recognized.

Communicable Diseases. — A considerable number of microscopic plants and a few microscopic animals have formed the habit of living for at least a part of their lives in other plants and animals. Two general causes of disease result from this parasitic habit. The parasite may destroy certain cells of the body, or the material thrown off from the body of the parasite may act as a specific poison.

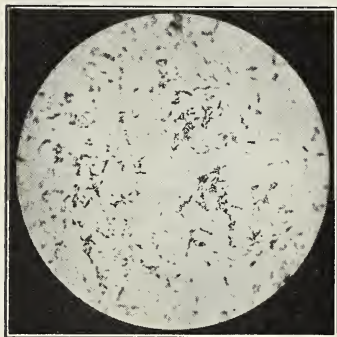
The term *communicable disease* is used in this book to mean a disease caused by a plant or animal living as a parasite in plants, animals, or man. These diseases are communicated in various ways from one person to another, from one animal to another, or from one plant to another.

The following are among the most common communicable diseases. Diseases caused by bacteria (minute plants) are tuberculosis, pneumonia, diphtheria, typhoid fever, bubonic plague, whooping cough, and scarlet fever. Measles is so similar to these in many ways that it is believed to be caused by bacteria, although the definite bacterium has not been discovered. Diseases caused by Protozoa (minute animals) are malaria, yellow fever, sleeping sickness, possibly smallpox, and others less well known.

Manner of Infection. — The biological diseases are all preventable, especially the communicable diseases which result from the parasitic habit of some plant or animal. In order to prevent people from being infected with these diseases, it is necessary to know how the minute plants and animals gain access to the human body and live there. This can be illustrated

by describing pulmonary tuberculosis, a plant or bacterial disease, and malaria, an animal or protozoan disease.

393. Pulmonary Tuberculosis. — Pulmonary tuberculosis is a disease located in the lungs. The cause is a definite plant, called *Bacillus tuberculosis*, with parts and habits which are easily recognized by bacteriologists (students of bacteria). These tuberculosis bacteria, or germs, are found in countless numbers living as parasites in the lungs of a tuberculous patient. The bacteria are extremely minute, and can be seen only by the use of a microscope of high power.



Dr. Henry Jones

FIGURE 458. BACILLI OF TUBERCULOSIS

The germs in the lungs rapidly increase in number, and are set free in the air by coughing. One tuberculous patient may give off millions of these germs in a day. For this reason great care should be taken in destroying the *sputum*¹ of patients, for if the germs become dry, they are carried about as dust particles.

Tuberculosis and other disease germs are so numerous that it is impossible to escape taking some of them into our bodies, but they usually do us no harm unless we are in a weakened condition.

Modern methods of cleaning the streets by flushing with water, keeping garbage covered, and wiping up the dust in our homes instead of using the old-fashioned feather duster are doing much to keep down the number of germs in the air which we breathe.

Getting Well. — While a large number of people suffer from this disease, it is not necessarily fatal, especially if treated in the early stages. But many do not consult a trained physician until after

¹ Anything spit out ; saliva and material discharged from the lungs.

the disease has made considerable progress, and then it may be too late to effect a cure.

When the body gains the requisite amount of strength after the treatment shown in Figure 460, which means rest, good food, and fresh air, the disease and its germs are usually thrown off. Patent medicines and alcohol should be avoided.



FIGURE 459. TESTING AIR

Of what value are the results of this testing?

Dr. James Alexander Miller, President of the famous Trudeau Sanitarium located at Saranac Lake, New York, recommends the following nine points for the future control of tuberculosis: (1) more complete segregation of tuberculosis patients in hospitals; (2) better protection of those, especially children, who have come into continuous contact with tuberculosis sufferers; (3) the continuation of efforts for the discovery and treatment of tuberculosis in children; (4) the continuation of efforts against the dangers of bovine infections; (5) improving the general standards of living, particularly in regard to nutrition; (6) improved



FIGURE 460. THE TUBERCULOSIS CURE

Above: A sanitarium. Note the many windows.

Below: Cheerful patients resting outdoors.

health organization; (7) establishment of some sort of health insurance; (8) improvement of medical practice along preventive lines; and finally (9) continuation of constructive leadership.

In addition to pulmonary tuberculosis, physicians recognize tuberculosis of the throat, intestine, kidneys, brain, and joints.

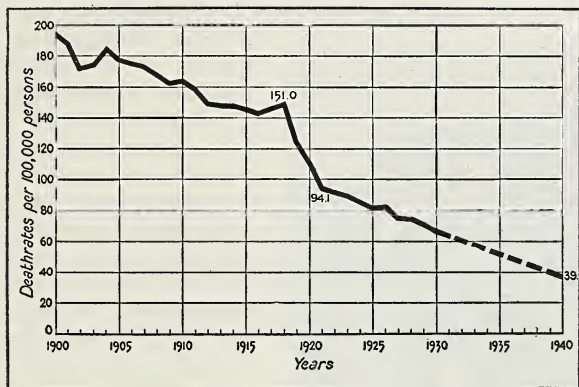


FIGURE 461. DEATH RATE FROM TUBERCULOSIS

The broken part of the line represents the expected rate. Notice how the rate has decreased since 1900.

394. Malaria, a Protozoan Disease. — Malaria is a disease caused by a protozoan or minute animal which is distributed over the greater part of the world. The malaria protozoan is a minute simple cell of living matter. It resembles the ameba in its form and ability to change. This parasite penetrates into the red blood corpuscles and remains in them for twenty-four or forty-eight hours, or until the substance of the corpuscle is nearly used up. Then the parasite escapes into the plasma of the blood and enters a fresh corpuscle.

Source of the Malarial Parasite. — The word *malaria* means *bad air*, for it was formerly believed that foul air caused the disease. When it was learned that a definite animal was the cause both in man and in other animals, the problem was to find

how the parasite entered the body. It has been proved to the satisfaction of scientists that the malarial protozoan is injected into the blood by a particular kind of mosquito (*Anopheles*) which carries malaria germs in its body. (See page 83.)

The mosquito sucks the blood from a man or an animal suffering from malaria. This blood contains some of the malarial



FIGURE 462. MOSQUITO CONTROL

This mosquito squad is cleaning out ditches in marshes where mosquitoes breed, thus allowing the free flow of water which washes out the larvæ.

parasites, which pass into the stomach of the mosquito. They then migrate into the salivary glands of the mosquito, so that as soon as the mosquito bites another man or animal, it pours out some saliva which introduces the parasites into the victim's blood. While in the body of the mosquito, these parasites pass through definite stages in their life history; and when they reach the blood of man, the remaining stages are completed. Thus a man, or an animal, and a particular mosquito are necessary for the complete life history of the malarial parasite.

This means in addition that for the prevention of malaria

all that is necessary is to prevent the *Anopheles* mosquito from breeding, or in case this cannot be done, to screen adequately the houses, tents, and bedrooms in the regions where these mosquitoes live. It is interesting to note that the methods for the prevention of malaria were more than anything else responsible for the successful completion of the Panama Canal. The construction of this important work was a health problem as well as an engineering problem.

As long as mosquitoes were regarded merely as pests, little effort was made to exterminate them, but as soon as it was discovered how destructive they are to human life, men everywhere began to study methods of eradicating them. In the numerous experiments that have been made to learn the true relation of mosquitoes to disease, men instead of animals have been used. Living mosquitoes which had bitten men with malaria were allowed to bite men who did not have this disease. These men then came down with malaria. In the same way yellow fever was proved to be caused by the mosquitoes technically known as *Aedes*.

395. Common Colds. — Most of us have from one to three colds during each year, which means that we suffer more from this disease than from any other. The common fallacy that colds are caused by exposure to drafts or sudden changes in temperature is widely held, but we take cold just as we take diphtheria or typhoid. Several different kinds of bacteria are found associated with the acute infections of the membrane that lines the passage of the nose and throat. Here are nine rules that will be helpful in avoiding colds:

1. Secure adequate sleep and rest (eight to ten hours' sleep every night with windows open, but under enough covering to keep warm).
2. Eat a moderate, mixed diet and partake freely, at regular periods, of pure water (six to eight glasses daily).
3. Wear clothing to suit the environment, particularly clothing which prevents chilling of the body surfaces and which keeps the body dry.
4. Avoid people with colds, especially those who are sneezing or coughing. There is more danger from contact with those just beginning to feel sick than from those ill enough to be confined to bed.
5. Keep out of crowds as far as possible, especially crowds in closed places.
6. Avoid the use of common towels, wash basins, glasses, eating utensils, and toilet articles.
7. Wash the hands thoroughly before eating.
8. Avoid the use of any so-called preventives. Vaccines, sera, and advertised preventives seem to be of little value and may be harmful in this disease, unless advised by a physician.
9. Avoid alcohol and stimulants of all sorts.

396. Quarantine. — When a person or a group of persons is suffering from a communicable disease, or when any one has been

exposed to the germs of any such disease, the board of health may place him under *quarantine*. The nature of the quarantine depends on the specific disease and the laws of the town or state in which the person lives.

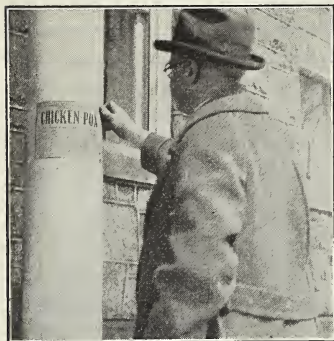


FIGURE 463. POSTING A QUARANTINE SIGN

Why is this necessary?

In addition to the quarantine of individuals in a dwelling, all the inhabitants of a city or state may be quarantined in case of severe epidemics; or the transportation of stock from one state to another may be prohibited in the case of a serious communicable disease existing in cattle or sheep.

Immigrants suffering from certain diseases are prohibited from landing in the United States. This means that there are national as well as state

and city quarantine laws. The present quarantine laws are the most effective protective measures against the spread of disease known to man and are the product of a high degree of civilization.

397. Immunity. — Each disease caused by a definite kind of bacterium has its own history of events as it begins, develops, and gradually recedes, but the biological principles are similar to those in tuberculosis. As soon as scientists were clearly convinced that a specific set of symptoms was due to a definite germ, they began trying to discover some way to prevent the disease. They have been partly successful. Some of their most important discoveries are about the facts of *immunity*. A person is immune to a biological disease if his body resists its germs so successfully that he does not “take” the disease. In the case of scarlet fever and diphtheria, tests have been discovered that show whether or not a person is immune.

Natural Immunity. — Many persons do not become sick when there is an epidemic of typhoid fever, measles, malaria, or the

like. Such persons have a *natural immunity* to those diseases. This immunity varies with the condition of the body; a person who is ordinarily immune may become susceptible to a disease if he is exhausted by care or work.

Acquired Immunity. — Those in the class who have not had measles probably have a natural immunity to measles. Those who have had measles now have an *acquired immunity* to measles.

Immunity is acquired in two ways: (1) by an attack of a disease; many germ diseases give immunity against another attack, but this is not true of all diseases or for all persons; (2) by immunization treatment.

398. Immunization. — There are two kinds of immunization by treatment: (1) the *active* (by inoculation), which is produced by the individual's own response to a disease germ or its toxin¹; (2) the *passive* (with an antitoxin), in which the substance which resists the germs is developed in the body of an animal and then introduced into the circulatory system of the person being immunized.

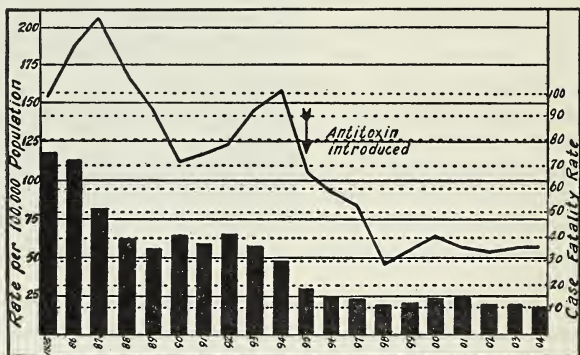
399. Inoculation. — Inoculation is the act of introducing into the circulatory system the virus² of a disease. Each disease has its own virus, and this virus produces a mild form of the disease. This causes the cells to become resistant to the germs or microbes of the specific disease. Inoculation is being widely used for the prevention of typhoid fever. All soldiers are required to take this treatment, and those who travel extensively and thus have to drink all kinds of water and milk should certainly undergo inoculation. The immunity given by typhoid-fever inoculation lasts possibly two years.

Inoculation against a disease reduces the liability of death in case the disease is acquired, but it does not absolutely prevent the disease. If an inoculated person gets an overwhelming number of germs, he may have an infection of a slight kind. But the liability of contagion is reduced to a minimum.

¹ A toxin is a poisonous substance produced by bacteria. (§ 265)

² The contagious matter of a disease.

Vaccination. — The success which has attended the efforts of man to overcome disease is well illustrated by the case of smallpox. For centuries this disease was responsible for many deaths throughout the world. It is said to have existed in China centuries before Christ. Later it swept over Europe again and again. A famous French physician wrote in 1754 that every tenth death was due to smallpox, and that one fourth of mankind was either killed by it or disfigured for life. Smallpox was



American Association for Medical Progress, Inc.

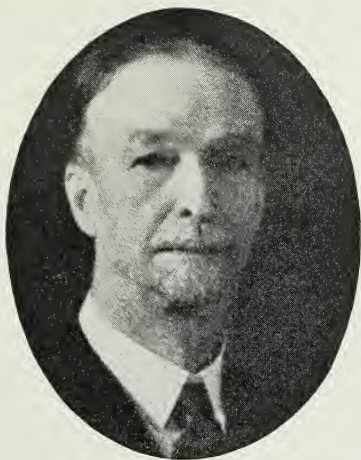
FIGURE 464. EFFECT OF ANTITOXIN ON THE DIPHTHERIA DEATH RATE

The zig-zag line traces the number of deaths from diphtheria in 100,000 of population.

The vertical bars show the percentage of diphtheria patients that died.

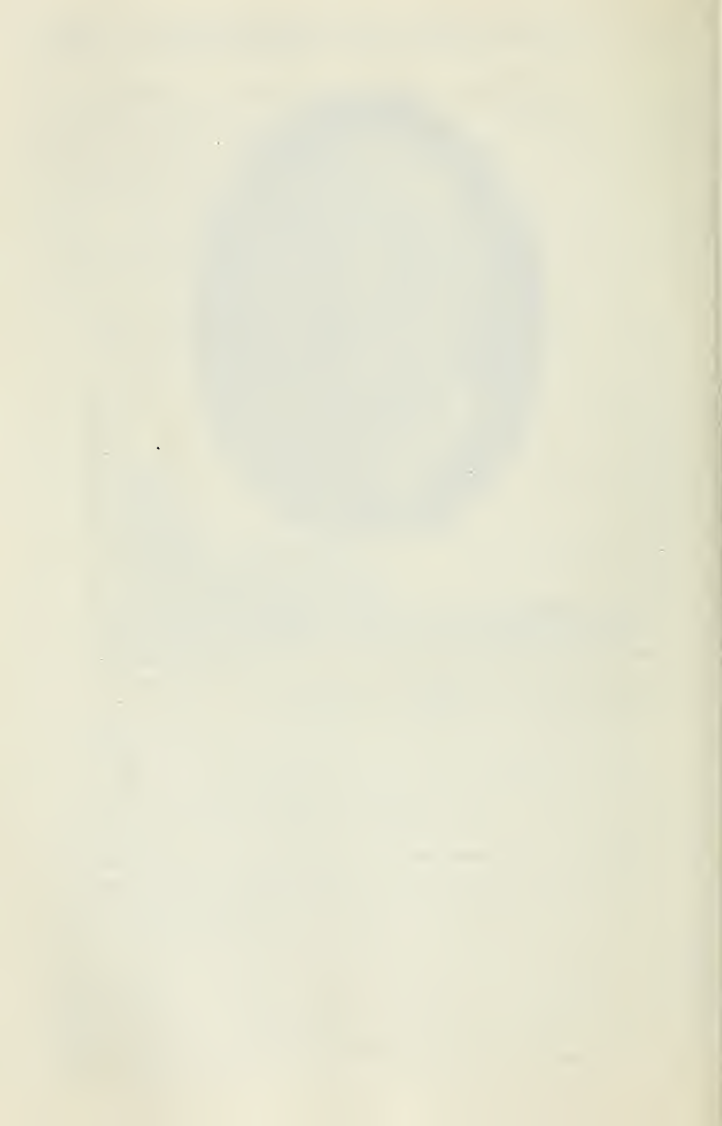
brought into the Western Hemisphere soon after the discovery of America, and killed thousands of the Indians. It also affected the colonists. In 1721, Boston was ravaged for the sixth time by this disease. Out of the 10,567 inhabitants, 5989 had the disease and 894 died.

In 1796, Jenner, an Englishman, demonstrated that inoculation with cowpox, a disease common in cows and in some way allied to smallpox, makes a person immune to the dreaded disease. This was one of the greatest and most beneficial discoveries about disease which has ever been made.



THEOBALD SMITH (1859-1934) was a technical scientist. The work of Professor Smith was to discover how disease germs live, and he was an acknowledged authority in his field. For his "original research and observation on the diseases of animals and men," he received the Copley Medal from the English Royal Society.

His best-known discoveries are as follows: 1. He discovered that the protozoan parasite in the blood of cattle which causes Texas cattle fever is also found in ticks. It is carried from one cow to another by the infected ticks. This discovery led to similar discoveries in malaria, sleeping sickness, and other protozoan diseases. 2. His scholarly researches in human tuberculosis have been of great value to mankind. 3. Present standards of meat inspection are based upon his investigations into the diseases of cattle and other food animals. 4. He was a pioneer in the manufacture and extensive public use of antitoxin.



As the result of vaccination and sanitation smallpox has become a rare disease in the civilized nations of the world, and is least prevalent where the vaccination laws are the most stringent. For most persons, immunity to smallpox, after vaccination, lasts several years.



Milbank Memorial Fund

FIGURE 465. A PRODUCT OF DISEASE

"Destitution is an 'end product' of neglected disease in 60 per cent of the cases. If sickness had been prevented, the destitution would not have followed. This points to the need of public health work which concerns itself with the prevention of the consequences of existing defects."

— Sir Arthur Newsholme.

The toxin-antitoxin treatment for diphtheria is a combination of the active and passive methods of immunization.

400. Prevention of Disease. — The old notion that children should be exposed to measles, scarlet fever, and whooping cough is wrong, for none of these childhood diseases is necessary. Our best doctors are spending much effort in showing how to avoid disease, for no one is benefited by illness. The time will

come when our homes and surroundings will be so sanitary that the common diseases caused by germs will be eliminated, or at least greatly decreased in number.

Carriers of Disease. — Another danger to health is from the people known as *carriers* of disease, who give no evidences of illness. Typhoid fever and diphtheria are the two diseases most likely to be carried in this way. Many hotels, public institutions, and well-run households insist that a prospective servant be examined by a competent physician before being engaged for work. In this way carriers may be detected, and persons with germ diseases, like tuberculosis, for instance, are prevented from spreading disease either in the food or in the air.

STUDENT REPORT

Copy the following report and fill it in. Do not mark your book. In cases which you do not know about, consult medical books or an encyclopedia.

DISEASE	DUE TO SOME PLANT OR ANIMAL		TREATMENT BY			PREVENTED BY				
	In the Water	From Contact	Nature	Medicine	Antitoxin	Personal Care	Quarantine	Boiling the Water	Fumigation	Killing Flies
Cold										
Measles										
Whooping cough . .										
Typhoid fever . . .										
Tuberculosis . . .										
Add others										

401. Epidemics. — Many people think that Americans are so well trained in ordinary questions of personal and civic hygiene that epidemics are impossible. But though many of us are familiar with the ordinary rules which science has devised for our protection, this knowledge will not prevent epidemics unless we see that everybody obeys the rules. Those of us who understand the real nature of communicable disease must take upon

ourselves the responsibility of helping to explain the cause of all such disease to those who are not so fortunate as to have had a course in biology.

The first measure to be adopted for the prevention of epidemics, and the one of greatest importance, is educational. Under this heading is included the knowledge: (1) that each germ disease is due to a specific germ, plant, or animal, living within the human

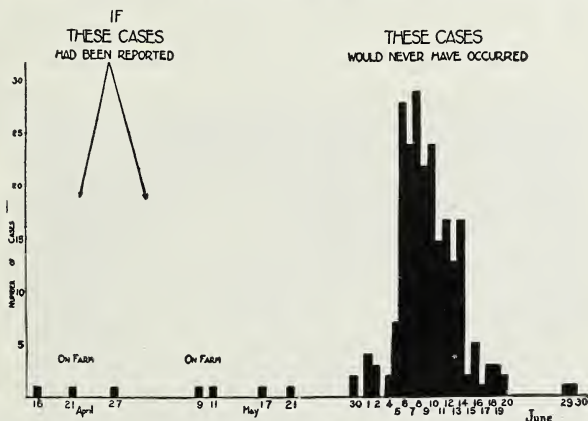


FIGURE 466. STORY OF THE EPIDEMIC OF SEPTIC SORE THROAT AT ROCKVILLE CENTER, LONG ISLAND

body; (2) that all germ diseases are preventable; (3) that keeping our bodies clean, eating clean, well-cooked food, and taking plenty of exercise will do more to prevent germ diseases than anything else we can do.

The second important measure to be adopted to prevent an epidemic *after the communicable disease has appeared* is the prompt quarantine of the first cases and immediately putting into operation the regulations of the board of health for communicable diseases.

The modern newspaper and radio give immediate publicity to new discoveries and this is a splendid service, but we need to remember that the science of biology has been taught less than

forty years in the high schools. The result is that all of us are too apt to jump to conclusions when we do not know all of the facts. Quacks and the makers of patent medicines are very clever in referring to new discoveries when they advertise their products, and because we are not well informed, we are tempted to buy fake remedies. If you are sick, consult a physician and take only such medicines as he advises.

402. Heredity and Disease. — The term *heredity* means a passing on from parents to their offspring. In the case of a biological disease which is caused by some definite plant or animal, it is evident that it cannot be inherited. But when the parents are afflicted with such a disease, their bodies become weakened and their children may have a poor constitution, so that they are more easily affected by disease.

403. Mental Health. — Biology is turning its attention to the study of the relation of disease to the normal working of our minds. That our minds may become diseased and insanity or some other abnormal state follow is generally recognized by students of the mind. In 1930 there were in the United States a total of 291,077 patients in State Hospitals for Mental Disease. Several of the states do not have a State Hospital for such patients, so that the total number of human beings with some form of mental derangement is without doubt much greater than this total. We find that in 1928 the capital investment in government hospitals was over \$1,400,000,000 and that about \$185,000,000 was annually given over to the care of mental disease and tuberculosis.

Alcoholism constitutes one of the main causes of insanity, and social conditions which contribute to faulty mental adjustment another. Under these two general headings we may place nearly 50% of the insane. Thus we are brought to face the fact that about half of these unfortunate sick human beings have become insane unnecessarily. We should realize that insanity is a sickness, not a disgrace.

The time has come to recognize that certain kinds of insanity are preventable and that it is not necessary for minds to go

wrong. Dr. Floyd Haviland, who was a noted student of insanity before his untimely death, gave the following five reasons for mental breakdown :

1. The tendency of individuals to avoid and evade obstacles and disagreeable circumstances
2. Letting emotions and feelings determine the individual's judgments and guide his actions
3. Excessive depreciation of self and others
4. Irritability and undue suspicion
5. Morbid fears, impulses, envy, hate, and shyness



FIGURE 467. TESTING WATER

Ewing Galloway

This bacteriologist is making his daily test of the water supply for a large city. Why is this necessary?

404. National and International Public Health Activities. — The problem of keeping water and food in a pure condition is often more than one state can manage, and the control of some of these activities has been taken over by the national government. In the same way there has grown up a conviction that one nation cannot adequately regulate conditions when a world-

wide distribution of a disease exists. For example, malaria and yellow fever exist in all parts of the tropics. Leprosy is almost wholly an Oriental disease. Cholera and typhus fever are confined mostly to the Eastern Hemisphere, while hookworm belts the world in an area extending about 33 degrees on each side of the equator. Such conditions call for international coöperation, and the Health Division of the League of Nations is accomplishing a great deal in preventing disease.

405. Special Health Agencies. — There are a number of valuable organizations supported by private contributions, one of which is the Rockefeller Foundation, chartered in 1913 to promote the well-being of mankind throughout the world. The large resources of this private foundation are almost entirely spent on public health and medical education. The trustees of

the foundation have contributed several millions of dollars to the establishment of schools of hygiene and public health at the Johns Hopkins and Harvard universities, and have made large additional gifts to selected medical schools in the United States, Canada, England, and China.

The discoveries of scientists constitute an absolutely essential step, but unless these discoveries can be made effective

by being put into practice, they are of no avail. For instance, scientists learned that certain fish were very beneficial because they fed on mosquito larvæ, but it was necessary to distribute such fish in the regions where malaria and yellow fever were prevalent before any benefit could result. The Rockefeller Foundation helped to introduce these fish (Figure 468) into Mexico in 1922.

Any enumeration of important public health activities must include the Red Cross, an international and national voluntary



FIGURE 468. TWO KINDS OF MOSQUITO-EATING FISH

Malaria has been routed from Istria, Italy, by the introduction of these fish.



W. T. SEDGWICK (1855-1921), a member of the Department of Biology and Public Health at the Massachusetts Institute of Technology for thirty-eight years, devoted his training and energy largely to making cities healthful. He was one of the foremost American biologists in making investigations upon milk, water, sewage, and epidemics of typhoid fever, and in showing how to apply these technical studies to human welfare.

He was one of the first to study the bacteria of the air, and his *Principles of Sanitary Science and Public Health* (1902) was an important contribution to public health education. He devoted his life to teaching biology and sanitary science and to training biologists and public health workers, and rendered a great service to the world by leaving it safer to live in than he found it.



SIR JOSEPH LISTER (1827-1912) was born at Upton, Essex, England. His great achievement was the recognition of the relation between the cause of fermentation which Pasteur's discoveries revealed and the cause of decomposition in wounds. In 1867 he published his famous article, "On a New Method of Treating Compound Fractures, Abscesses, etc. with Observations on the Condition of Suppuration," in the English medical journal, *Lancet*. Lister reasoned that if fermentation and putrefaction were due to living organisms, then suppuration had a similar cause. This focusing of attention on living organisms carrying on their physiological processes and the discovery that carbolic acid prevents this activity laid the foundation for antiseptic surgery. Every hospital in the entire world employs the principles which this famous Englishman first applied. It is impossible to calculate the number of lives that have been saved and the suffering that has been prevented through the introduction of scrupulous cleanliness into surgical operations.

society. The Red Cross holds itself in readiness to offer the best scientific assistance that can be given in times of great disasters, such as earthquake and fire, floods, tornadoes, droughts, war and other serious and unusual conditions.

The work of these several public health agencies varies from year to year, and you will find it interesting to make a special investigation of their work during the year that you study biology.



FIGURE 469. A MODERN OPERATING ROOM

406. Modern Surgery.—Modern surgery began with Sir Joseph Lister, who in 1867 announced his practical application of the germ theory to wounds. He said: "When it had been shown by the researches of Pasteur that the septic property of the atmosphere depended, not on oxygen or any gaseous constituent, but on minute organisms suspended in it, which owed their energy to their vitality, it occurred to me that decomposition in the injured parts might be avoided, without excluding the air, by applying as a dressing some material capable of destroying the life of the floating particles."

This method of Lister, greatly modified and improved, has been universally adopted. Until Pasteur or some one else discovered germs and the fact that they gave rise to fermentation changes, the marvelous results of Lister were impossible.

Modern surgery takes great care to prevent germs from getting into the openings which have been made to correct abnormal conditions. The knives and other instruments are sterilized. The air in the operating room is free from dust. The surgeon and nurses wear masks so that germs from their noses or throats may not escape into the air. This is *aseptic* surgery. In *antiseptic* surgery less care is used in the operating room, but all cuts are treated with germicides to kill the germs that may have entered. A strong human body may manufacture its own anti-toxin and thus neutralize the poisons of such germs as are not killed, and the patient makes a good recovery. The advantages of aseptic surgery over antiseptic surgery are self-evident.

407. Conservation and the Future. — The death rate among human beings is being lowered by applying the results of scientific discoveries about health and disease. International coöperation is bringing under control world-wide diseases that destroy man, animals, and plants.

Advance in science must wait for the work of individuals who have those qualities of mind that enable them to solve problems that no one else can. We are too prone to pass lightly by great minds because their work is not spectacular, although daily we enjoy the results of their labors. The men who lost their lives trying to discover the cause of yellow fever and the value of X-rays in the treatment of disease are among our greatest national heroes. They died trying to find out a method by which the lives of millions of people might be prolonged. A nation is safe when it has such heroes. It is in danger when it forgets them.

SUMMARY

Disease prevents us from working as we do when we are well. Most diseases are unnecessary and preventable, especially those which are caused by plants or animals living as parasites in our bodies. In most of the bio-

logical diseases some definite poison produced by the parasite is taken into the body, and this is the chief cause of disease. Tuberculosis, the "great white plague," is caused by a plant named *Bacillus tuberculosis* and often referred to as "TB." One can get well if the body is able to overcome the poisons secreted by these minute plants. Each disease caused by bacteria has its own special history and the symptoms of the disease are definite and distinct.

As a physician knows the nature of a disease and its effect upon the body, he can aid materially in overcoming the illness. Each biological disease is distinct and must have special treatment. Many of these diseases are taken from some one who has the disease. Inoculation, antitoxin, and quarantine are measures which help to prevent the spread of germ diseases.

The diseases that are transmitted by mosquitoes are malaria and yellow fever. The general rules to be followed with mosquitoes are to:

- (a) Prevent so far as possible all mosquito propagation.
- (b) Kill all mosquitoes possible of those which do breed.
- (c) Keep habitations away from mosquitoes and mosquitoes away from habitations.
- (d) Protect the sick from mosquitoes.
- (e) Protect the well from mosquitoes.

It was the application of these rules that made the building of the Panama Canal possible and life there as safe as in the temperate zones.

Conservation of human beings is the greatest problem that we have to solve. Immense progress has been made through scientific discovery. Municipal, state, national, and international agencies are making effective these discoveries. Many private agencies are making great contributions to conservation through their researches and by distributing the new information all over the world.

QUESTIONS

What are the biological diseases? How are these diseases caused? How many kinds of tuberculosis are there? Is diphtheria a germ disease? Are colds germ diseases? Describe malaria. What effect has malaria had upon the settlement of our country? (This is a home study question.) What is vaccination? What is quarantine? For what diseases are people quarantined? What are public health activities? How are they carried on? Why are laws necessary in connection with public health activity? What conclusions do you draw when you discover that a country has practically no health laws? Name some of the agencies that are helping the advancement of public health.

SPECIAL TOPICS FOR DISCUSSION

1. What are the health agencies in your locality?
2. Where do you get your water supply?
3. What are the methods of disposal of the sewage in your community?
4. Do you believe in quarantine?
- 5. Do you support the anti-tuberculosis campaign?
6. Do you believe in the Red Cross?

REFERENCES

- Celli-Eyre, *Malaria*, Longmans, Green and Company
Chalmers, *The Beloved Physician*, Edward L. Trudeau, Houghton Mifflin Company (1916)
Chapin, *Sources and Modes of Infection*, John Wiley and Sons
Conn, *Bacteria in Dairy*, Middletown, Conn.
Cornell, *Health and Medical Inspection of School Children*, F. A. Davis Company (1912)
Edelman, Mehler, and Eichorn, *Textbook of Meat Inspection*, Lea and Febiger (1925)
Knopf, *History of Tuberculosis, a Preventable and Curable Disease*, National Tuberculosis Association (1922)
Rosenau, *Preventive Medicine and Hygiene*, D. Appleton and Company
Stiles, *Prevalence and Geographical Distribution of Hookworm Disease*, Hygienic Laboratory, Bulletin Number 10, Washington
Trudeau, *An Autobiography*, Garden City Publishing Company

CHAPTER XXXVI

HABIT-FORMING DRUGS AND TOBACCO

*Ill habits gather by unseen degrees,
As brooks make rivers, rivers run to seas.*

— OVID

408. Man, an Exception. — In the section on Human Biology, constant reference was made to the similarities between man and animals and, in many instances, to plants. Here we must place man in a class by himself, for he is the only living thing that finds that drugs and tobacco present a problem to be solved.



FIGURE 470. ROLLING TOBACCO FROM PLANTATION TO WHARF IN THE EARLY DAYS OF AMERICA

Recent excavations reveal that man concocted beverages containing alcohol several thousand years B.C., and the history of morphine and cocaine antedates modern civilization. Columbus on his first voyage to America saw the natives using tobacco. In this section of our study, we are brought face to face with one of the ancient problems of mankind. Drugs and tobacco are in no way indispensable to our health and happiness, and if we

are as independent as we pretend to be, we shall not find in them any individual problem.

No one can make a really accurate statement of the total number of persons addicted to drugs. Reliable authorities place the number of persons in the United States taking morphine alone at more than 150,000. We have already noted the relation of alcohol to insanity (page 524).

From the earliest records down to the present, there have always been persons who were unable to use the habit-forming drugs in moderation. The disastrous results fill many books and reach out into the economic, social, political, and idealistic phases of human existence. The evidence growing out of this long experience is conclusively against their use. This is one of the problems that man has not solved. What has science to contribute that may serve as a helpful guide for you?

409. Habit-Forming Drugs. — These are alcohol, opium, morphine, codein, heroin, cocaine, and various patented preparations. Drugs are special preparations used to relieve pain or to increase or slow down the activity of certain cells. Most drugs, when taken in doses greater than the usual amount prescribed by a physician, may cause death. It is customary to use such terms as poison, anæsthetic (ăn'ēs-thět'ik), and narcotic to describe the results arising from the use of these drugs. Some substances, like opium, have the nature of all three. A poison is a substance which when taken into the body tends to cause death or serious injury to health. Opium, carbolic acid, and mercury are poisons, and when taken in sufficient quantities, cause death.

An anæsthetic is a substance like ether or chloroform, which when breathed into the lungs causes a temporary loss of consciousness. Unless anæsthetics are administered properly, they may cause death.

A narcotic is a substance which causes dullness or stupor, and even a temporary relief from pain. The narcotics often have a temporary quieting effect which is sometimes associated with a pleasurable feeling. The common narcotics are opium,

chloroform, cocaine, laudanum, chloral hydrate, alcohol, nicotine, and various patent preparations.

Many preparations are taken by persons ignorant of the fact that they generally contain these harmful drugs. It should be sufficient to know that no reputable doctor will ever give any of these narcotics except in case of extreme pain. No person except a physician has a right to prescribe drugs, and he only after a knowledge of the patient's symptoms. Many of these preparations affect the heart and blood, and none of them has any beneficial effect, except in the temporary relief of pain.

Many people take some of these narcotics under a physician's directions without becoming drug users. But those who continue their use find that the dose first taken no longer produces the same sensations. The morphine taker is a good example. Through the habitual use of morphine, he becomes less and less susceptible to its immediate effects, and has constantly to increase his regular dose in order to obtain the effect he desires. This is the most insidious feature of the drug habit. The fact that the victim must take larger and larger doses as he becomes used to the drug means that the harm done his body becomes greater and greater, although not in direct proportion. His general health and strength become much impaired, and he loses weight steadily. Finally his nervous system is badly injured and he becomes insane and dies.

410. Alcohol. — Alcohol is a poison. The alcohol habit grows similarly to the morphine habit, although alcohol apparently is not a habit-forming drug to the same degree as opium or morphine, but its effect in this respect is different in degree rather than in kind. When it is taken in large amounts, death results. When taken in sufficient amounts to produce stupor or temporary loss of control of the body, a definite narcotic condition results and the individual cannot carry on his usual activities.

Many people can drink a certain amount of alcoholic beverages and still retain control of their faculties. But no two persons exhibit the same reaction to alcohol. Because one individual

can retain control of himself after drinking a certain amount, it is no indication that another can.

In this connection a further significant condition enters the problem. If one drinks when the stomach is empty and consumes the liquor rapidly, the reaction is much more pronounced than when it is taken slowly. The reason for this is that alcohol is absorbed directly into the blood without undergoing digestive



FIGURE 471. THE WHISKY TELESCOPE

He sees the future of the man who acquires the liquor habit.

changes and thus a larger amount of alcohol is quickly brought to act on the cells of the body. These two facts, first, individual differences in the tolerance of alcohol, and secondly, the rate at which alcohol is introduced into the body, explain one phase of the effect of alcohol on man.

Laboratory tests show that when the concentration of alcohol reaches about five milligrams for every cubic centimeter of the blood, a state of coma follows with complete loss of consciousness. But at present it is not practical to make such tests, and science has not agreed upon any other accurate method of measuring the effect of alcohol on man.

There are three stages that can be recognized in the absorption of alcohol: first, the excitation stage due to the removal of the controlling influence of the brain; secondly, the period of non-coördination in which physical and mental balance and poise are upset; thirdly, the stage of stupor in which only strong stimuli bring about a response.

There is general agreement that alcohol is more detrimental to the nervous system and brain than to any or all other organs in the body. The reason given for this conclusion rests on the scientific fact that the nervous organs and brain contain a greater proportion of a fat known as lipid. A few years ago scientists discovered that any substance which dissolves lipid, or is dissolved in lipid, is an anæsthetic. Chloroform, ether, and all other agents used in modern surgery to produce unconsciousness are dissolvers of lipid. Besides acting as an anæsthetic these substances act as poisons.

There is no evidence that even a small amount of alcohol will not damage the brain or weaken the moral strength of an individual. Persons who take sufficient alcohol to enter the period of non-coördination usually lose their sense of decency and civilized propriety. The temporary satisfaction claimed by those who use alcohol should be weighed against the final effects in habitual drunkards who lose not only shame, modesty, and pride in personal appearance, but are especially liable to certain common diseases and to insanity.

A large and growing number of physicians are of the opinion, based on experience, that alcohol is rarely useful or necessary as a medicine in the cure of disease. Alcohol is known to decrease the power of the body to withstand disease and it does not assist in destroying the poisons which arise in the case of bacterial diseases.

Alcohol as a Food.—Alcohol when taken into the digestive tract does not undergo digestive alteration but is absorbed into the blood in an unchanged condition. In this respect, alcohol differs from most foods although we do find that grape sugar is absorbed as grape sugar. This peculiarity of alcohol permits rapid absorption into the blood, and thus affords a readily available source of energy; a peculiarity which explains why if a person suddenly collapses alcohol may be used advantageously.

After the alcohol is taken into the blood, it is oxidized in the same manner that the common foodstuffs are oxidized and furnishes energy to the body in a similar manner. When we

take an extra amount of the usual foodstuffs into the body, these may be stored in the tissues for future use, but in the case of alcohol it remains in the blood until it is oxidized or excreted.

When alcohol exists in high concentration in the blood, it seems to have a limiting action on its own oxidation, and this may

prevent the oxidation of other material, so that the presence of a considerable amount of alcohol in the blood tends to prevent the normal processes of oxidation taking place. The really beneficial food value of alcohol is so limited that in the judgment of many, it is insignificant.

Alcohol and Efficiency. — Modern methods of experimentation with their more precise measurements of human reactions can detect losses of efficiency from quantities of alcohol that were long considered harmless. It had been thought that one could not take enough, to affect his work, of so weak a drink as a beverage containing

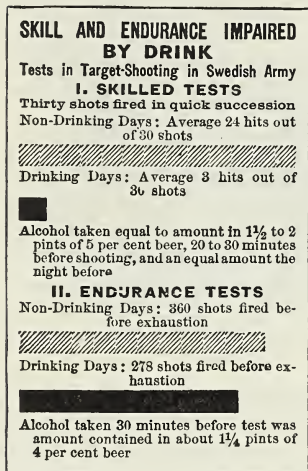


FIGURE 472. EFFECT OF ALCOHOL ON NERVOUS EFFICIENCY

only 2.75% alcohol, but experiments have proved the contrary. Among the most exhaustive of the tests in this field are those of Dr. Walter R. Miles at the Carnegie Nutrition Laboratory, Boston, 1924. Only one of the several tests is given, the one that called on faculties used in different kinds of everyday work. It is as follows :

The instrument used had a needle which received quick and irregular impulses to swing in one or another direction. The person being tested has to counteract these efforts by movements of a handle to bring the needle back to the proper point. . . . The "2.75 per cent" alcohol doses impaired ability to do this kind of work in seven out of eight men tested. In six of them the

work was impaired over 10 per cent. In one the impairment was as much as 32.7 per cent. The average impairment was about 14 per cent. The effect was most marked at one hour and twenty-five minutes after taking the alcohol. — WALTER R. MILES, *Alcohol and Human Efficiency* (page 254). Carnegie Institution of Washington, March, 1924.

The following is abstracted from *A Report of the Advisory Committee of the British Liquor Control Board on Alcohol: Its Effect upon the Human Organism*.

An Englishman, Dr. Vernon, found that both with himself and with four students who were tested with typewriters and adding machines, the errors increased after taking about a pint of claret wine. The typists seemed not to be able to control their muscles so well as when they had taken no alcohol.

Before scientific investigation had developed precise methods of testing mental faculties, visible signs of drunkenness were taken as the earliest indication of alcoholic injury. But experiments like those already cited show that harmful effects of alcohol begin long before the state of drunkenness is reached.

The harmful effect of alcohol taken in large quantities at one time or in smaller quantities regularly over extended periods of time has long been recognized. But people did not understand until shown by recent scientific investigation why a tendency to reckless drinking often appears soon after the first glass or two, or why the moderate drinker should be in danger of gradually increasing his allowance. Now we know that the functions of the higher brain centers, on which depend self-judgment and self-control, are the first to be weakened by the effects of even small amounts of alcohol, so that when a drinker passes beyond moderate limits in drinking it is because this power of self-control has been weakened.

Alcohol in "Patent" Medicines. — Many "patent" medicines contain a considerable amount of alcohol. Since the passage of the national Food and Drugs Act, which became effective in January, 1907, the presence and quantity of alcohol in "patent medicines" have to be declared on the label. This alone tended to reduce the amount of alcohol in many preparations but there still remained a large number whose most active and powerful drug was alcohol, and the United States government would not permit them to be sold except under a liquor license.

Dr. Haven Emerson, former Health Commissioner of New York City, gives the following summary of alcohol:

1. Alcohol is a depressant, habit-forming drug.
2. Alcohol is a protoplasmic poison.

3. Alcohol reduces resistance to disease.
4. Alcohol increases liability to accident, and delays recovery.
5. Alcohol reduces endurance, accuracy, and rapidity of muscular action of all kinds, even when used in such small amounts as to show effects inappreciable to the user.¹

411. Opium.² — On July 13, 1933, a new world-wide opium pact went into effect. This is known as the League of Nations Convention for Limitation of Manufacture of Narcotic Drugs. This agreement marks a great step forward in the efforts of man to control narcotics. In order to put these new regulations into practice, the opium-growing nations had to place human welfare ahead of economic gain. This has never been done before.

We should take pride in the long and continued efforts of the United States to regulate the production of opium and suppress the opium traffic. The United States was the first nation to sign the new convention. It took twenty years to bring about this recent agreement, for it was only in 1912 that the first International Conference on the Regulation of Opium was held at the Hague.

Few of you who study biology are likely to become addicted to the use of opium, morphine, or similar habit-forming drugs. However, you should know that one notable authority says that the use of habit-forming drugs for thirty days is long enough to establish the habit in most people and that after this period the struggle is so severe that few can overcome the craving.

The drug addict is unable to play his part in the game of living because he cannot be trusted. When we realize that the best parts of our modern civilization would have to be thrown over

¹ Those who are interested in making a more critical study of the relation of alcohol to the various forms of activity of man and animal should consult the two volumes, *Physiological Aspects of the Liquor Problem*, edited by John S. Billings, Houghton Mifflin Co., Boston; also, *The Action of Alcohol on Man*, by Ernest H. Starling, Longmans, Green & Co., 1924; *The Defenses of the Body against Alcohol*, Daniel — *Popular Science Monthly*, page 159, 1924. Emerson, *Alcohol and Man*, 1932. British Liquor Control Board. Printed in United States. Senate Report, No. 1105, 72nd Congress. Cutten, *The Psychology of Alcoholism*. Horsley and Sturge, *Alcoholism and the Human Body*.

² Terry and Pellens, *The Opium Problem*, will give help to those who wish to learn something of the extent and difficulties of this problem.

if there were not human beings upon whom we could rely to carry out their particular tasks, we have some appreciation of the seriousness of acquiring a habit that destroys trustworthiness. Try to think of some task that you would be willing to turn over to a drug addict.

412. Patent Medicine. — While any one who understands biology will shun the opium habit, there is another phase of this same problem that, due to our ignorance and credulity, may come very close to us. There are many medicinal preparations that contain varying amounts of habit-forming drugs. These are usually spoken of as “patent” medicines and are put up in packages to be taken as the purchaser wishes and are sold under some proprietary name.

During the past thirty years important changes have taken place in the “patent” medicine industry, the most important being due to restrictive legislation. All of the legislation and the active enforcement of these acts by the United States Government have had but one end in view; to prevent the sale of habit-forming preparations to those ignorant of their composition and unaware of their nature. Many of these preparations contain opium or some of its derivatives. It is impossible to estimate the damage done to human beings by the widespread sale and use of these preparations. Pain-killers, cough cures, soothing sirups, infant reliefs, paregoric, and many other “medicines” contain these drugs.

We should not be surprised if many persons who became dependent in youth on these preparations later turned to the opium habit. In 1927 the total sales value in the United States of “patent” medicines containing narcotics was \$646,139. The habit-forming drug is still a serious question even though we have protective legislation. You can do your part in contributing to the solution of this problem by refusing to purchase such preparations.

413. Tobacco.¹ — When Columbus discovered our land, he also discovered tobacco. He saw the natives place the short

¹ Mendenhall, *Tobacco*, “Harvard Health Talks,” gives an excellent account of the tobacco problem.

branches of a Y-shaped hollow stick in their nostrils and the stem in the smoke of burning tobacco. The smoke was inhaled directly into the nostrils. It was not until 1558 that tobacco was introduced into Europe. The French ambassador at Lisbon, Jean Nicot, in 1561, was much taken with the new plaything. It is from his name that the term *nicotine* comes. The story is told



FIGURE 473. A TOBACCO FIELD

Notice the drying barn.

that a servant saw clouds of smoke coming from the mouth of Sir Walter Raleigh, who was one of the first to smoke in England, and quickly seized a pail of water and dashed it into his face.

If you care to look up the economic phases of smoking, you will be amazed at the amount spent annually for tobacco. In 1928 approximately \$3,000,000,000 was the total for the United States or \$12.50 for each adult. One of the special economic aspects that is of interest to us all is the annual fire loss that is ascribed to the use of tobacco. In this same year no less than \$30,000,000 is the damage charged to the carelessness of smokers.

There has been from the time that Europeans first began to smoke a sharp difference of opinion over the effects of this habit. Tobacco is harmful to those who have a low tolerance to nicotine and to those who smoke to excess. In many ways the tobacco and alcohol problems are similar. The medical profession and practically every one else agrees that children and young people should not use either tobacco or alcohol.

Cigarettes and Eyes. — When cigarettes are burned, several poisons are produced. Nicotine, carbon monoxide, hydrocyanic acid, puridine, sulfureted hydrogen, picolin, and lulidin are some of the toxins that have already been isolated from tobacco. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in large quantities by the lungs when the smoke is inhaled. Many persons, even adults, are made ill whenever they absorb these poisons, and any competent physician can detect the detrimental effect of smoking on young people.

Some recent investigations¹ on the influence on the eye of smoking prove conclusively that the poisonous effects are more marked and serious than the earlier studies revealed. Inflammation of the optic nerve, which seems to act on certain nerve fibers only, is thus produced. This causes a defect in the central field of vision first for green, then for red, and finally for blue and white. There is also an alteration in the size of the "blind spot" in some smokers. When these symptoms appear, they can be relieved only by completely ceasing to use tobacco. If the person who is subject to tobacco toxemia does not abstain, then permanent blindness may follow. Since this habit of smoking has been taken up by girls and women who do not seem to have the resistance to these poisons that most men have, these toxic signs frequently develop within a few months after the use of tobacco has been begun.

"Training starts to-morrow, no more smoking," is part of the athletic coach's orders at the beginning of each season. He

¹ We are indebted to Dr. David F. Gillette, Syracuse, N. Y., for these facts concerning the influence of smoking on vision.

knows that the boy who smokes cannot reach his highest efficiency or be relied upon at critical times in the contest. He would rather have boys who do not smoke, because they are stronger, larger, and steadier than those who smoke. The cigarette habit has spread until it is undermining the health of thousands of boys in America to-day. How is it known that their health is not good? The charts on "smoker's heart" prove this point.

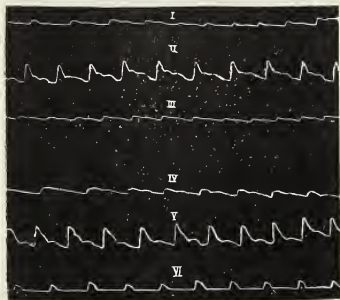


FIGURE 474. EFFECT OF TOBACCO ON THE HEART BEAT

How the Smoker's Heart Is Affected. — The following illustrations on the rate of the heart beat and the strength of the pulse, by W. A. McKeever, for thirteen years professor of philosophy in Kansas University, show what really happens when we smoke. There is much in these illustrations to warrant the conclusion that the heart of the habitual cigarette smoker is weak and feeble,

except for the few minutes during which he is indulging in the habit, and that the pulsations at this time are unduly excited. Figure 474 shows three records of a young man nineteen years old who began smoking cigarettes at the age of fifteen and who inhaled the fumes. The three records were taken without removing or readjusting the instrument, as follows: No. I, immediately before smoking, No. II, during the indulgence in the habit, and No. III, fifteen minutes later, after the effect of the narcotic had become apparent. Now, by reference to Figure 475, No. III, we may observe how this young man's heart should record itself, for the latter is the tracing of the heart pulsations of a normal young man of the same age and temperament. Nos. IV to VI (Figure 474) are representative of another inhaler twenty years old, who began the practice at thirteen. He now uses a strong pipe.

In Figure 475, Nos. I and II, taken respectively before and after smoking, are tracings of a sensitive youth of eighteen who has been smoking only two years. Observe the skip of his heart beat at *x* and the corresponding partial skip under the stimulus of smoking in No. II. No. III (Figure 475), as mentioned above, is a tracing of a strong, healthy heart of a young man of somewhat excitable temperament. No. IV represents the phlegmatic temperament; that is, a person who is not excitable. No. V is the heart tracing of a strong and healthy non-smoking young woman.

Says Mr. McKeever :

From the foregoing evidence we are led to the conclusion that in the case of boys and youths, cigarette smoking is very deleterious to the physical and mental well-being. Moreover, my investigations indicate that it makes very little difference in the effects whether the victim uses pipe or cigarettes, provided he inhales the fumes; and with few exceptions the young smokers are inhalers. The ordinary case exhibits about the following type of conduct: (1) While the craving is at its height the victim manifests much uneasiness and often much excitation. (2) During the indulgence the cheek is alternately flushed and blanched, the respiration considerably increased, and the hands tremble. (3) About twenty minutes after smoking the muscles become relaxed, the respiration slow and shallow, the skin on the face dry and sallow, and there is an apparent feeling of unconcern about everything.

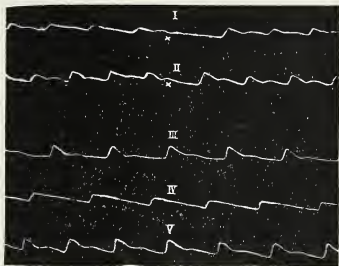


FIGURE 475. HEART BEATS OF A SMOKER AND NON-SMOKERS

When cigarettes are burned, three distinct poisons are produced which cause serious effects on persons who inhale tobacco smoke in this form. These poisons are absorbed in small quantities by the mucous membrane which lines the nasal passages and in larger quantities when the smoke is inhaled into the lungs. It makes little difference whether the smoke comes from cigarettes, cigars, or pipes. All kinds are harmful, especially when inhaled.

Though we can all gradually adapt ourselves to small amounts of poison, they are never beneficial unless prescribed by a physician to try to remedy some bodily defect. The poisons which arise from the burning of tobacco are never prescribed even as medicines, and have never been found in any way beneficial to the human body.

SUMMARY

Man has used beverages for thousands of years and has not yet learned that their use constitutes an important problem for him to solve. The degree to which individuals can drink alcoholic beverages varies. When taken in sufficient amounts, it is a definite narcotic. There is no legal agreement on what constitutes drunkenness. Alcohol is a food of limited value. The habit-forming drugs should be avoided and it is important to be on the alert in the temporary use of preparations that contain them. Tobacco is an expensive luxury that used to excess produces serious results.

If you insist on smoking, answer the following questions on safeguards that should be observed :

QUESTIONS

Why should you :

1. Wait till growth is complete at twenty-five years?
2. In the use of cigarettes restrict yourself to not more than eight each day?
3. Smoke only immediately after meals?
4. Use dry tobacco?
5. Do not inhale smoke or blow it through your nose?
6. Use a cigarette holder?
7. Have a complete physical examination once each year?
8. Stop smoking for a month each year?

CHAPTER XXXVII

BIOLOGY AND VOCATIONS

'Tis no sin for a man to labour in his vocation. — SHAKESPEARE

414. Need for Guidance. — You have nearly completed a year of study of the lives of animals and plants and of the biological behavior of your body. You now realize that biology makes an important contribution to human welfare *provided we take advantage of the facts that science has discovered and apply them intelligently to our daily lives.* The keen competition between those animals and plants that seek to live, though useless to man, and those that man utilizes is so great that men trained in special and technical fields of biology are needed to help control them. This is one of the important problems that man has to solve. Here is a list of some books dealing with problems you should understand in choosing a life work :

Adams, *Women Professional Workers*, The Macmillan Company
Allen, *A Guide to the Study of Occupations*, Harvard University Press
Bernaye, *An Outline of Careers*, Doubleday, Doran
Davis, *Guidance for Youth*, Ginn and Company
Earle, *Methods of Choosing a Career*, Harrap and Company
Filene, *Careers for Women*, Houghton Mifflin Company
Hatcher, *Occupations for Women*, Southern Women's Educational Alliance
Kitson, *How to Find the Right Vocation*, Harper and Brothers
Lyon, *Making a Living*, The Macmillan Company
Rosengarten, *Choosing Your Life Work*, McGraw Hill Publishing Company

415. Vocational Possibilities in Biology. — A group of teachers prepared this list of vocations dependent on a knowledge of biology :

Physician	Veterinarian	Bacteriologist	Oral Hygienist
Dentist	Nurse	Entomologist	Farmer
Pharmacist	Laboratory Assistant	Nurseryman	Horticulturist
Dietitian	Sanitary Engineer	Landscape Architect	Tree Surgeon
Teacher	Oculist	Forester	Optometrist

A person may have an occupation and yet be unfitted for it. This may result in discouragement and in serious mental disturbance so that the person produces a poor product and loses his job. Aptitude tests are given in the field of medicine when the student applies for entrance, and other tests may be worked out in other fields. The purpose is to conserve human effort by determining a person's adaptability to a certain profession. As fast as such tests are perfected, we should take advantage of them ; for different persons have different abilities and each should do the best he can with his biological equipment.



FIGURE 476. TRAINING TREE SURGEONS

These men are learning about trees and what troubles them. Would this be an interesting vocation? What part does biology play in it? .

We should learn what is involved in choosing a career. The list of books on page 554 will tell you why you should secure a broad general education before you enter upon your chosen work.

Next you should select the biological field that has the strongest interest for you and learn all that you can about it in regard to (a) advantages, (b) disadvantages, (c) essential qualifications as to personality, (d) qualifications as to health, (e) training necessary and where obtained, (f) rewards.

416. Biological Hobbies. — You know that the study of biology gives you an understanding of how your body behaves, and you have noted the various fields of human activity that are dependent on some phase of biology. We shall now turn to a consideration of the ways in which biology may furnish recreation to those of you who do not make a vocation of it.

We suspect that many of you may have been tantalized during this year of study because the text gave too brief a story of some animal or plant that interested you; and you should begin your recreation in biology where you have found some particular plant or animal about which you wish to learn more.

You will soon find that elementary books are too brief and that you must explore the library to learn how much is really known; but even this source of possible information may fail to tell

you all that you need or wish to know, so you must observe and patiently study your friend, for such the plant or animal you are studying has now become. What does it do summer and winter, spring and autumn? What devices does it possess that are especially helpful in its peculiar form of life? What enemies must it escape? Here are some suggestions for further reading:

REFERENCES

Allen, A. A., *The Book of Bird Life*, D. Van Nostrand and Company
Beard, Dan, *The American Boy's Book of Bugs, Butterflies, and Beetles*, J. B. Lippincott Company



Ewing Galloway

FIGURE 477. INTEREST IN INSECTS

It is fun to pass on information you have gained in following your hobby.

Bose, Sir Jayadis Chunder, *Plant Autographs and their Revelations*, The Macmillan Company

Dixon, *The Human Side of Birds*, F. A. Stokes Company

Dixon, *The Human Side of Plants*, F. A. Stokes Company

Downing, *Our Living World*, Longmans, Green and Company

Harwood, *New Creations in Plant Life*, The Macmillan Company

Lutz, *Field Book of Insects*, G. P. Putnam's Sons

Morley, *Wasps and Their Ways*, Dodd, Mead and Company

There is no end to the possibilities for biological hobbies. Here we outline but the following three: (1) Fun for a Lifetime, (2) Photography, (3) New Discoveries.

417. Fun for a Lifetime. — Some persons have their fun playing golf, dancing, going to the movies, taking part in politics, reading history, poetry, or stories. What are you going to do in your leisure time? Biology offers many attractive opportunities, one of which is to become well acquainted with the life in your near-by parks, fields, or woods. In each of these you will see a great many kinds of trees, flowers, insects, and other living things. How should you go about learning their names? Possibly the most conspicuous kinds of life will be trees, grasses, flowers, and insects. If you have selected an ordinary park for your fun you can group the trees into (1) the cone-bearing, narrow-leaved, soft woods, called conifers; and (2) the broad-leaved hardwoods which do not bear cones. This is the first step in learning the names of trees. You would probably find only a few conifers and only ten or fifteen hardwood trees, although there are some 530 different kinds of trees in America north of Mexico.

The grasses would be more difficult to name, for this group contains about 7000 species. However, not very many kinds would be found in any one park, for only about 700 kinds of grasses grow in the United States.

You would certainly find some wild flowers, even if the park were well kept, because there will be a number of weeds which bear flowers. All in all, you would find a rather large number of flowering plants for all of the grasses and all the trees, except the

conifers, and all of the weeds would have to be included. There are possibly 125,000 different sorts of flowering plants. You have learned in Chapter XX the parts of a flower, and these will be most useful to you in determining the different kinds of flowering plants.



FIGURE 478. A VISTA OF FLOWERS

This is a field of blue lupine in Paradise Valley, Rainier National Park.

If you were to wander about the park and become more familiar with the plants, you might notice here and there clumps of mosses. These plants do not bear flowers nor do they produce seeds. The mosses represent a large subdivision of the plant kingdom, — 380 different species and varieties have been described in the vicinity of New York City alone, and it has been estimated that there are over a thousand species of mosses in the United States.

The more you explore the park and the more observing you become the more different kinds of living things you will find. You would soon notice dark green patches on the bark of some of the trees. If you could gather some of these patches and take

them to the laboratory and observe them under a microscope, you would find that they were very small plants and that they belonged to still another independent division of the plant kingdom. If there were water in the park, there would undoubtedly

be a number of different kinds of plants which grow only in the water.

You would probably find also some colorless plants known as mushrooms or toadstools, and these would introduce you to another large division of the plant kingdom. If you ever become interested in the study of the fungi, you



FIGURE 479. OYSTER MUSHROOM

An edible mushroom which grows on wood.

will be astonished to find the great variety of places where these interesting plants live. The number of kinds of fungi is not accurately known but calculations indicate that it is between 32,000 and 150,000.

If you carried your study in the park still further and investigated the microscopic life, you would find decaying material harboring millions of microscopic plants called bacteria. Any park which you might begin to study would become full of meaning in view of the large number of different plants that usually gain a living in a small area.

But some of you will say that you are not interested as much in the plants. Are there any animals in the park? Certainly there are, and they, like the plants, present equally interesting problems for your study. There are probably 13,000 different kinds of fish and at least 1400 species of frogs, toads, and salamanders; the snakes, turtles, and alligators include 35 different sorts of animals. There are probably as many different kinds of birds as there are fish. After you have identified all of the vertebrates in the park, it would be impossible for you not to have

seen beetles crawling along the path, mosquitoes feeding on your blood, or butterflies flitting about. Insects would certainly be well represented in any park, for they are more numerous than all other groups combined. No one knows how many kinds of insects there really are, but the men who study them have described 250,000 kinds of beetles and 120,000 species of moths

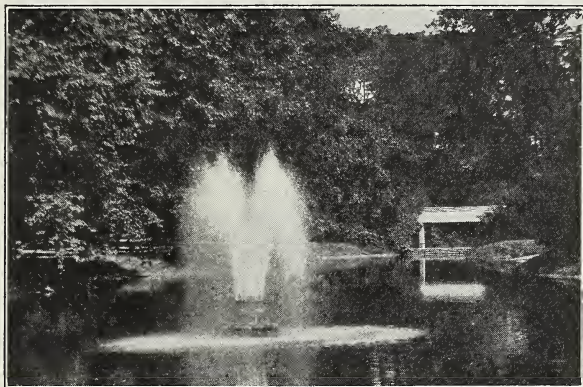


FIGURE 480. THE "BUG-CATCHER"
General Electric Company

Our parks and ponds can be made both beautiful and useful. This hatchery pond has colored electric lights to attract insects, which are washed into the water by the spray. This is known as the "bug-catcher."

and butterflies. Bees, ants, and wasps are represented by more than 86,000 species, while the flies account for 75,000 more. There are many other groups of insects besides these just mentioned, so that the total number of 625,000 kinds of insects is easily estimated. The experts in this field believe that if all the insects in the world were identified, there would be at least two and a half million, and some of the enthusiastic students claim that there would be ten million.

But even after you have finished naming all of the vertebrates and insects in the park there would still be many other different kinds of animals to be studied. The group to which the earth-

worm belongs contains about 4000 species; then there are the roundworms and the flatworms numbering together about 6500 species. If you pressed your investigations still further into the microscopic life in water and specialized on protozoa, you might devote a lifetime to their study, for there are more than 8500 different kinds.

William Thomas Councilman, who taught the technical subject of pathology in Harvard Medical School for thirty years, shows us ¹ how one person went about "having fun for a lifetime." "One of Dr. Harvey Cushing's chief joys was the Arnold Arboretum, and his knowledge of every shrub and tree in that marvelous place was scarcely exceeded by that of his greatly admired friend, Charles S. Sargent, the Director. When he retired from his teaching, he shifted his research efforts from the diseases of man to those in plants, and his latest printed paper, issued from the Arnold Arboretum, describes a disease in trailing arbutus. After he completes his account of this disease, he reveals his deep attachment for the trailing arbutus (*Epigæa repens*), which has, as he says, a fatal gift of conspicuous beauty; 'The *Epigæa repens* is one of the most beautiful and interesting of plants. Its blossoms, which are among the earliest of the spring flowers, are white or pink with a waxy texture and a delicious spicy odor and are borne at the extremities of the stems. The pale green hairy leaves and the pale pink or green stems streaming from the center close upon the surface of the soil add to the attractiveness. The environment of dead brown leaves, mosses, and low plants give a perfect setting. It is unfortunate that these wonderful qualities should be those which are ensuring the destruction of the plant.

"By great care and skill plants can be transferred to other suitable localities and may even be propagated by seed but there is little prospect of this ever becoming a garden habitant. . . . This desire to save the plant is not a mere matter of sentiment. No plant is more suitable for . . . the awakening in children through its study the all important wonder and curiosity.'"

¹ William Thomas Councilman, "Harvey Cushing," *Science*, Vol. 77, 1933.



FIGURE 481. IN THE ARNOLD ARBORETUM

These views were taken of approximately the same locations. Notice the differences between the summer and winter views, and yet each is a lovely scene.

Here are some references for guidance for those choosing one of the fields of biology as a career :

Allen, F. J., *Studies of Occupations in Agriculture, Forestry, and Animal Industry*, Harvard University Press, 1921

American Medical Association, *Choice of a Medical School* (15 cents)

Davis, M. M., *Hospital Administration; a Career*, 1929. Published by the author

Dean, E. O., *Opportunity of Out Doors*, 1921. Harper Brothers (deals with Landscape Architecture)

Gres, W. J., *Dental Education in the United States and Canada*, The Carnegie Foundation, No. 19, 1926

Haupt, A. C., *Nursing as a Profession*, Women's Occupational Bureau, Minneapolis, Minn.

Iowa, State University of, *Dentistry as a Profession*, University of Iowa Bulletin, No. 221, 1922

Iowa, State University of, *Pharmacy as a Profession*, University of Iowa Bulletin, No. 171

Moon, F. F., and Brown, N. C., *Elements of Forestry*, N. Y., Wiley, 1929

National League of Nursing Education, N. Y., *Opportunities in the Field of Nursing* (free)

Odencrantz, L. C., *The Social Worker in Family, Medical, and Psychiatric Social Work*, Harper and Brothers, 1929

Pack, C. L., and Gill, Tom, *Forests and Mankind*, The Macmillan Company, New York, 1930

Sherman, E. A. (U. S. Forestry Service) *Forestry as a Profession*, Superintendent of Documents, Washington, D. C. (15 cents)

Spring, S. N., *The Profession of Forestry*. Forestry training at the New York State College of Forestry at Syracuse University, State College of Forestry, Syracuse, New York, 1932

Stead, W. H., *Opportunities for Women Trained in Home Economics*, Women's Educational Bureau, Minneapolis, Minnesota, 1928

Tracy, Martha, *The Profession of Medicine and Women's Opportunity in This Field*. Journal of the American Association of University Women, Volume XXI, October, 1927

U. S. Department of the Interior, Office of Education. (Government Printing Office) Guidance Leaflets :

Forestry	.05
Opportunities for a Life Career in the Field of Public Health, 1924	.15
Medicine	.05
Nursing	.05
Pharmacy	.05
Veterinary Medicine	.05

INTERESTING SUMMER READING

- Addams, Jane, *Twenty Years at Hull-House*, 1910, The Macmillan Company
- Beebe, C. W., *Nonsuch-Land of Water*, 1933, Putnam
- Berry, Elmer, *The Philosophy of Athletes*, 1927, A. S. Barnes Company, New York
- Calvert, M. R., *The First Course in Home Making*, Smith Hammond
- Connor, R., *The Doctor*
- Cook, E. T., *Life of Florence Nightingale*
- Curie, M., *The Story of My Life*, Delineator, 1932
- Cushing, H., *The Life of Osler*, Clarendon Press
- De Kruif, P., *Hunger Fighters*, Harcourt Brace and Company
- De Kruif, P., *Microbe Hunters*, Harcourt Brace and Company
- Finney, J. M. T., *The Physician*, Charles Scribner's Sons
- Greer, C. C., *Foods and Home Making*, Allyn and Bacon
- Grenfell, W., *Autobiography*
- Harris and Lacey, *Everyday Foods*, Houghton, Mifflin Company
- Kelley, H., *Walter Reed*
- Kinyon and Hopkins, *Junior Foods and Clothing*, Sanborn and Company
- Kinyon and Hopkins, *Junior Home Problems*, Sanborn and Company
- Lanman, McKay, and Zuill, *The Family's Food*, J. B. Lippincott Company
- La Wall, C. H., *Four Thousand Years of Pharmacy*, 1927, J. B. Lippincott Company
- Matthews, M. L., *Elementary Home Economics*, Little, Brown and Company
- May and Petgen, *Leisure and Its Use*, 1928, A. S. Barnes Company
- Reid, E. G., *The Great Physician (Osler)*, Oxford Press, 1931
- Robinson, V., *Pathfinders in Medicine*, Medical Life Press
- Somers, Florence, *Principles of Women Athletes*, 1930, A. S. Barnes Company
- Trilling and Williams, *The Girl and Her Home*, Houghton Mifflin Company
- Trudeau, *Autobiography*
- Valery-Rodot, R., *The Life of Pasteur*, Doubleday, Page and Company
- Wayman, Agnes, *Education through Physical Education*, 2d Edition, 1928, Lea and Febiger, Philadelphia
- Willard, *Nutrition for High School*
- Williams, J. F., *Textbook of Physical Education*, 1931, Saunders Company, Philadelphia
- Woolsey, T. S., *Riding the Chuck Line. A Forester in Peace and War*, New Haven, Tuttle, Morehouse and Taylor
- The biological vocations are also treated in Adams, Filene, Hatcher, and Bernaye listed on page 545.

418. Photography. — Every one enjoys trying to solve a mystery. That is the reason that detective stories are so engrossing. Many of us are equally charmed by the writings of those who have learned some of nature's mysteries. When you have ferreted out one of nature's secrets, write it as a story or make a permanent record of it with your camera. The written story will contain your ideas of what you have seen, while the camera records the fact. Do the two agree?



*Photographed by Hobart V. Roberts for the New York State College of Forestry,
Syracuse University*

FIGURE 482. PHOTOGRAPHY

Here a picture is being taken of two deer, caught unawares.

If you decide to enter this fascinating field of discovery, you will need to make a very thorough study of the technique of making pictures. You may recall how carefully the photographer posed you before taking your picture; he probably made several pictures in order to see which pose made you look best. You must make a similar study of the animal and plant you have chosen, but your difficulties will be increased many times because you must not make an artificial setting for the subject you select.

The successful nature photographer is first of all a keen student of biology, for he must learn in detail the habits of the particular animal or plant that he wishes to photograph. The light must be good, though he has no control over the weather. If his ambition is to make a record of the night habits and activities of

his animal, he must study the various methods of artificial illumination, and when this technical detail is understood, the animal must be found and a place selected that will permit a picture of good composition. Some nocturnal animals can be made to take their own picture if you set up a camera which has the bait attached to a flashlight that snaps the camera (Figure 178).

Most of you send your snapshots to a commercial photographer who develops and prints them, but he does not know what you wish to emphasize. If you are to become a real nature photographer and get all the fun that this activity gives, you must learn to develop and print your own negatives. Mastering the art of developing and printing your own negatives will give you a satisfaction that you will never get by turning it over to some one else to do. Let your imagination reconstruct the steps that went into the making of the perfect wild animal picture shown in Figure 483.

One of the most notable achievements in photographing plants in their natural surroundings is recorded in the two volumes, *Wild Flowers of New York*, by Dr. Homer D. House. The pictures are so natural that one recognizes that the author is a true naturalist who has a sympathetic understanding of plants. Many of his pictures came to successful completion only after

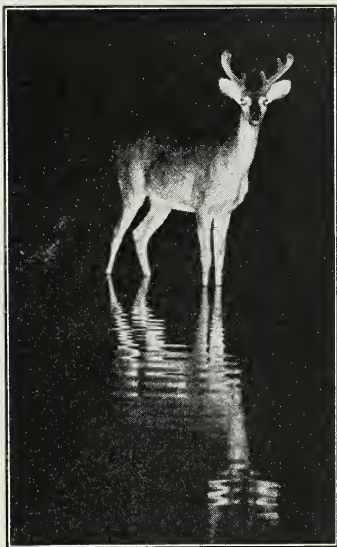


FIGURE 483. ONE OF THE DEER

This is the result of the picture being taken in Figure 482. The deer, startled by the flash, has looked up just in time to make a lovely picture.

months of search for the rare plant, and his camera record may be our only glimpse of it. Until you have tried to make similar pictures, you cannot realize how much critical information is demanded nor will you experience full satisfaction from your hobby.



FIGURE 484. AN EVERGREEN GROWING ON A WILLOW TREE

The seed of the evergreen was lodged in the willow tree, took root, and grew. Isn't it an interesting photograph?

419. New Discoveries. — You have but to contrast the life of Cro-Magnon man with your own to realize how much progress man has made in gaining control of his environment. Two factors have contributed to this change: first, scientific discoveries; second, the intelligent application of these discoveries to everyday life. Perhaps you wonder how so many discoveries have been made in recent years. This question can be easily answered. When some one finds a new animal or plant and announces his discovery, it simply means that it has been seen and described for the first time. This animal or plant may have been living in the same region for hundreds of years.

All new discoveries have been made by men and women who once were boys and girls as you are, with possibly no notion of the way in which they were to help to make this world a better or more interesting place to live in. There is still much to be learned about plants and animals, and some of you should prepare yourselves to have a part in making new discoveries. So much has already been learned that it will be necessary for you to spend a number of years before you will have sufficient training to try to solve any of nature's secrets.



A



B



C



D



E

FIGURE 485. THE DEVELOPMENT OF A NEW APPLE

A, blossoms with stamens removed ; B, tree with bags on blossoms ; C, cage containing seeds ; D, seedlings ; E, orchard trees two or three years old.

It will be important, if you are ambitious to make new discoveries, to learn how skillfully a professional biologist plans out the steps in making a new discovery, for it is only by exercising equal care and skill that you are likely to succeed in your quest.

It requires many experiments before a superior apple is produced, for hardly one in a thousand trials is successful. These experiments require patience, labor, and money. Many people choose this line of work for a "hobby," and some notable discoveries have been made in this way.

If you were to ask Dr. U. P. Hedrick, of the Geneva Experiment Station, which of his many discoveries about fruits gave him the most satisfaction, he might reply, "My effort to produce a better apple than any one had previously done." To do this the new apple must have an attractive color and good flavor; it must mature late in the fall. The McIntosh apple is a popular apple with many favorable points. He believed that a better apple than the McIntosh could be grown and one that would ripen a month later. After studying the several varieties and the possibilities of cross-fertilization, he decided to use the McIntosh and Ben Davis. This is the way in which he proceeded:

First, the stamens of the flowers of the Ben Davis apple were cut away to prevent self-pollination.

Second, pollen from the flowers of the McIntosh was put on the stigmas of the Ben Davis flowers to pollinate them.

Third, paper bags were put on these flowers so that no other pollen could reach them and make uncertain the results.

When the apples of the Ben Davis, thus cross-pollinated, were ripe, they were picked, and the seeds were removed. These seeds were put in a wire cage and buried in the earth to keep them moist and safe from rodents. The following spring the little seedlings were planted in plots and kept free from weeds.

In 1906, eight years after the experiment was made, these seedlings had grown to be trees large enough to blossom and bear fruit. Now the question that interested Dr. Hedrick and his staff of experts was to be answered. Presently the small apples began to form. Would they ripen before McIntosh, with McIn-



“LIKE LIVING COALS THE APPLES BURNED”

This might well be called a perfect reproduction of a perfect specimen of
a perfect apple, the Cortland.



tosh, or later? As time went by, Dr. Hedrick found they would not ripen before McIntosh; neither would they ripen with McIntosh, but later, just as he had hoped. The color was superior to McIntosh and the flavor just as good. The new apple hung to the tree better than the McIntosh. Now the biggest question of all remained to be answered: Would the public buy the apple as readily as they bought McIntosh? The experiment proved to be a success economically as well as biologically. As we look at this beautiful fruit, the Cortland apple, we can appreciate the skill and patience of the scientist who labored to develop it. Was it not worth while?

Test IV

I. Write your answers to the following on a separate sheet of paper.

1. Give two advantages of having the blood pass through the lungs, one advantage of having it flow in the walls of the small intestine, and one advantage of having it pass through the liver.
2. What first-aid treatment would you give in case of a cut artery?
3. Where does respiration actually take place in the body?
4. What is a useful product or result of the process of respiration?

II. Copy the following statements and indicate by use of + and 0 which are false and which true.

1. Sugar is stored in seeds in large quantities.
2. Liquids pass up a stem through the bark.
3. All arteries carry blood containing a large supply of oxygen.
4. Heat is produced in the body by the oxidation of the tissues.
5. Most absorption of food takes place before the food reaches the large intestine.

III. On a separate sheet of paper write the words *oxidation* (respiration), *photosynthesis*, and *osmosis*. Under three words write the number of each statement that is most closely related to the corresponding heading.

1. Takes place within the cells of plants and animals.
2. Requires CO_2 and H_2O .
3. Is dependent on sunlight and chlorophyll.

4. Takes place through the walls of the root hairs.
5. Produces free oxygen.
6. Releases CO_2 .
7. Takes place through the walls of capillaries.
8. Requires two liquids of different densities.
9. Releases energy.
10. Requires oxygen and a substance containing carbon.

IV. Copy the following statements, filling in the blanks with the word or group of words that best completes the meaning :

1. The circulation of the blood was discovered by _____.
2. The living plant in a seed is the _____.
3. The physical basis of life is _____.
4. One of the best methods of preventing the spreading of epidemics is _____.
5. A process in green plants that is related to light is called _____.
6. "Prone pressure" is a means of _____.
7. A muscle between the chest and abdominal cavities in mammals is the _____.
8. The absorbing structures in the small intestine are called _____.
9. A respiratory opening in an insect is a _____.
10. The smallest unit of structure in living things is the _____.

V. Copy the number of each statement below and opposite it write the letter preceding the word or group of words that best completes its meaning :

1. Very dry air is undesirable because (a) it does not circulate easily; (b) it contains less oxygen; (c) it removes moisture from the body; (d) it contains too much dust; (e) it contains more germs.
2. When oxygen unites rapidly with other substances, the process is called (a) combustion; (b) evaporation; (c) condensation; (d) ventilation; (e) transpiration.
3. The codling moth lays its eggs on the blossoms of the (a) aster; (b) milkweed; (c) tomato plant; (d) corn; (e) apple tree.
4. Starch is changed to sugar by (a) pepsin; (b) saliva; (c) gastric juice; (d) blood; (e) lymph.
5. A class of foods used to produce growth and repair in the body is called (a) fat; (b) starch; (c) mineral matter; (d) protein; (e) vitamins.
6. The substances used in testing for starch is (a) nitric acid; (b) alcohol; (c) iodine; (d) ammonia; (e) hydrochloric acid.
7. The process by which digested foods pass through the walls of the alimentary canal into the blood is called (a) excretion; (b) absorption; (c) digestion; (d) evaporation; (e) transpiration.

8. When a person cannot take a contagious disease, he is said to be (a) disinfected; (b) sterilized; (c) pasteurized; (d) intoxicated; (e) immune.

9. Disease germs in our bodies are destroyed by (a) vitamins; (b) adenoids; (c) red corpuscles; (d) white corpuscles; (e) cilia.

10. The main purpose of respiration is (a) release of energy; (b) elimination of carbon dioxide; (c) manufacture of food; (d) excretion of wastes; (e) purification of air.

VI. Most of the following are the names of digestive agents: ptyalin, mucus, saliva, gastric juice, bile, pancreatic juice, diastase, plasma, intestinal juice. From this list select and list the following:

1. Three agents that digest starch.
2. Two agents that digest protein.
3. One that acts as a lubricant.
4. One that digests fats.
5. One that changes cane sugar to grape sugar.
6. Two that digest foods in the small intestine.

VII. Write your answer to the following on a separate sheet of paper:

1. Name a disease caused by each of the following: improper diet; improper function of a gland; a microscopic animal.

2. Name three contagious diseases and state one method of controlling or preventing each disease named.

3. To whom is the power given to direct the methods for the control of disease in any community?

VIII. Name two ductless glands and three glands that have ducts. State one way in which a function of the human body is affected by each gland mentioned.

IX. Follow the directions given below.

1. In each of the groups of five terms below, there is one term that includes the other four. List these terms.

(a) stigma, pistil, style, ovule, seed

(b) mammal, whale, cat, bat, man

(c) protozoa, ameba, bacteria, paramecium, microorganism

(d) digestion, absorption, nutrition, respiration, assimilation

(e) dissolved food, red corpuscles, white corpuscles, plasma, carbon dioxide

2. In each of the groups of five terms below, four are alike or are related and the fifth word is different from the other four. List those that are different.

- (a) butterfly, potato beetle, frog, house fly, mosquito
- (b) respiration, digestion, circulation, assimilation, pollination
- (c) ostrich, bat, robin, bluebird, eagle
- (d) pistil, sepals, filament, root hairs, petals
- (e) malaria, scarlet fever, measles, whooping cough, diphtheria

X. Copy the following statements, filling the blanks with those words which best complete their meaning:

- 1. Food is oxidized in the cells to produce heat and _____.
- 2. Green plants are able to make _____ in the sunlight.
- 3. Substances pass through a membrane by the process of _____.
- 4. Water contains _____ and oxygen.
- 5. If lime water becomes milky in color, _____ is present.
- 6. Matter is found in three states: gas, liquid, and _____.
- 7. The _____ is the unit of organic structure.
- 8. Chromosomes are found in the _____ of the cell.
- 9. The chemical union of oxygen with another element is called _____.
- 10. Burning a match is an illustration of a _____ change.
- 11. All the living matter within a cell is called _____.
- 12. Forests, wild animals, coal, etc., are _____ resources.
- 13. _____ is the element that supports combustion.
- 14. Sugar is a compound composed of _____, hydrogen, and oxygen.
- 15. Water freezing into ice is an illustration of a _____ change.
- 16. Reproduction by cell division is called _____.
- 17. Energy may be transformed but not _____.
- 18. The eggs of the crayfish are attached to the _____ on the abdomen of the female.
- 19. Like the grasshopper, the crayfish has an abdomen composed of a number of _____.
- 20. The head and _____ regions of the crayfish are united into one.
- 21. The crayfish secures _____ from the water by gills.
- 22. Crustaceans do not _____ at the change of the season like birds and some fish.
- 23. Spiders have _____ pairs of legs.
- 24. _____ of lost parts is common in the crustacea.
- 25. Permanent resident birds do not _____.
- 26. Birds generally have _____ toes on each foot.
- 27. Birds have a bill composed of mandibles without _____.
- 28. The _____ of birds are homologous to the fore limbs of the animals.

29. The bones of birds are _____ or have spongy cavities.
30. In California the _____ has been propagated for its feathers.
31. In 1850 the _____ was introduced into the United States.
32. Migratory insect-eating birds are now protected by a Federal treaty with _____.
33. Many scientists believe that birds developed from _____ partly because fossils of extinct birds have teeth.
34. The _____ are the breathing organs of the fish.
35. The upper part or back of the animal is called the _____ side.
36. There are _____ pairs of fins on the ventral side of the fish.
37. Each gill has three parts: rakers, bony arch, and _____.
38. The gill rakers strain particles of _____ from the water.
39. Frogs catch insects by a quick movement of the _____.
40. Our game laws should aim to protect the fish during the _____ season.
41. Both fish and frogs are cold _____ animals.
42. Caviar is made from the eggs of the _____.
43. During the winter frogs are in a state of _____ in the mud.
44. Eels migrate downstream and deposit their eggs in the _____.

APPENDIX

CLASSIFICATION OF ANIMALS AND PLANTS

Some of you may wish to consult from time to time a general plan of the grouping of animals and plants. Scientists the world over have accepted the form of classification as given below for the distinctive and clearly defined forms of life. When we wish to give a specific animal or plant its complete name, we employ Latin terms mostly; and each term has an accepted relation to all other terms in the series. We may illustrate this feature by giving the frog its full name. It is a Chordata, an Amphibia, an Anura, Ranidae, *Rana pipens*. Should you wish to locate exactly in the scheme of classification a given plant or animal, you will find it necessary to consult books that specialize in this phase of biology. Gray's *Botany* specializes in the flowering plants of the eastern part of the United States. Pratt's *Manual of the Common Invertebrate Animals* is an excellent reference for this group and Jordan's *Manual of Vertebrates* is indispensable. Then there are many books that deal with the mosses, ferns, reptiles, birds, etc.

CLASSIFICATION OF ANIMALS

1. PROTOZOA. Animals without any special organs such as heart or brain. Mostly single-celled, aquatic in habit, a few forms parasitic. *Examples*: ameba, malarial parasites, paramecium. Pages 330, 333, 515.
2. PORIFERA. The sponges. The body is made up of two simple layers and has a skeleton of horny lime or glasslike material. Page 334.
3. CŒLENTERATES. In this group are found the polyps, jellyfishes, and corals. There is a common form of organization in the widely differing 10,000 different kinds. Pages 322, 324.
4. PLATYHELMINTHES. The flatworms, common in fresh water and living as parasites, such as tapeworms. Page 119.

5. ROTIFERS. The wheel worms, often found in the fresh water with the protozoa. Termed wheel worms because of the special disk on the head end of the body.
6. NEMATHELMINTHES. The roundworms, very numerous. The body is not segmented. Hookworms, threadworms. Page 120.
7. ANNELIDS. The segmented worms. Earthworms, sandworms. Page 121.
8. ECHINODERMS. Starfishes, sea urchins, and several other forms all having a limy exoskeleton and a definite and special system of locomotion. Page 117.
9. MOLLUSKS. One of the most numerous of the invertebrate groups. Soft-bodied animals which usually have the body covered by a shell. A highly specialized group with a peculiar muscular foot used in locomotion. Snails, clams, oysters, squids. Page 118.
10. ARTHROPODS. The most numerous of all the special groups of animals. They possess an external skeleton that is jointed, and have jointed, paired appendages. Those that live exclusively in the water and breathe by gills are termed crustaceans. *Example:* the crayfish. Pages 104-112.
Most of them are air-breathing forms such as:
Myriapods. Page 116.
Arachnids. Pages 115, 116.
Insects. Pages 53-103. For classification see below.

ORDER	PRONUNCIATION	DERIVATION	EXAMPLES
Orthoptera	ör-thöp'tēr-ä	<i>orthos</i> , straight + <i>pteron</i> , wing	grasshoppers, katydid's, crickets
Hemiptera	hê-mîp'tēr-ä	<i>hemi-</i> , half + <i>pteron</i> , wing	bugs
Coleoptera	köl'ê-öp'tēr-ä	<i>coleos</i> , sheath + <i>pteron</i> , wing	beetles
Hymenoptera	hî'mên-öp'tēr-ä	<i>hymen</i> , membrane + <i>pteron</i> , wing	ants, bees, wasps, sawflies, gall wasps
Odonata	ô-dôn'ä-tä	toothed (<i>odontos</i> , of a tooth)	dragon flies
Lepidoptera	lêp'î-döp'tēr-ä	<i>lepidos</i> , genitive of <i>lepis</i> , scale + <i>pteron</i> , wing	butterflies and moths
Diptera	dîp'tēr-ä	<i>di-</i> , twice + <i>pteron</i> , wing	flies, mosquitoes
Homoptera	hō-möp'tēr-ä	<i>homos</i> , similar + <i>pteron</i> , wing	cicadas, aphids, scale insects

11. **CHORDATES.** This is a general term for all of the animals described in this book as vertebrates. There are forms in addition to those included in this book which are very primitive in organization. The subdivisions of the vertebrates are as follows:

Pisces, fishes. Pages 124-139.

Amphibians. Pages 140-154.

Reptiles. Pages 155-160.

Aves, the birds. Pages 161-187.

Mammals. Pages 188-211.

CLASSIFICATION OF PLANTS

A. FLOWERLESS PLANTS (Cryptogams).

I. **THALLOPHYTES.** Plants without division into distinct roots, stems, and leaves.

1. **ALGÆ.** Unicellular, filamentous, and plate-like forms living chiefly in the water, flaccid, lightly attached or floating. In salt water are larger forms that resemble higher plants in size and in root-like holdfasts and branchings. Independent, food-making plants.

Blue-green, *Nostoc* and *Oscillatoria*. Pages 317, 318.

Green, *Pleurococcus* and *Spirogyra*. Pages 317, 318.

Brown, *Fucus*. Pages 317, 319.

Red, *Polysiphonia*. Pages 317, 319.

2. **FUNGI.** Unicellular, filamentous, and more highly organized forms from the smallest organisms known to those several feet in length. All lack chlorophyll, hence cannot make their own food and are dependent on organic matter, living or dead, for their food.

Schizomycetes, (fission fungi) Bacteria. Pages 338-348.

Saccharomycetes, (sugar-loving fungi) Yeast. Page 327.

Phycomycetes, (alga-like fungi) Breadmold. Page 325.

Ascomycetes, (sac fungi) Lilac mildew.

Basidiomycetes, (stalk fungi) Bracket fungi, mushrooms. Pages 326, 327.

Lichens, algæ and fungi. Pages 316, 325.

II. **BRYOPHYTES.** Plants that are learning to live on land. They demand a great deal of moisture and have rhizoids to gather it. They are green and independent but not highly organized.

Liverworts — flat, ribbon-like, with rhizoids along the midrib on the under side. Have alternation of generations, the gametophyte being the conspicuous generation, the other parasitic. Pages 316, 364.

Mosses — division into stem and simple leaves. The sporophyte generation lives as a parasite on the gametophyte. Pages 314-316, 364.

III. PTERIDOPHYTES. Larger plants than Bryophytes, with the sporophyte the important part of the life history, and the gametophyte a small, short-lived body on which the sporophyte lives for a short time.

Ferns — plants with leaves usually much divided. Pages 309-313.

Horsetails — plants in which the stem performs photosynthesis, and a special stalk produces spores. Pages 313, 368.

Clubmosses — creeping plants used for Christmas wreaths. Elaborate, spore-forming organs. Page 313.

Selaginella — a transitional form that shows the beginning of the seed-forming habit. Page 309.

B. PHANEROGAMS, SEED-FORMING PLANTS.

I. GYMNOSPERMS. Cone-bearing, usually evergreen plants, the seeds borne on naked scales. This group contains our largest plants. Pages 298-303.

II. ANGIOSPERMS. Flowering plants bearing their seeds in an ovary. This group contains the remaining plants. The green plant is the sporophyte generation. Pages 215-290.

PROMINENT FAMILIES

I. MONOCOTYLEDONS.

Lily family
Grass family
Sedge family
Orchid family

2. DICOTYLEDONS.

Rose family
Pea family
Mustard family
Flax family
Mallow family
Crowfoot family
Honeysuckle family

Consult botanies for other families.

BIBLIOGRAPHY

AUTHOR	TITLE	PUBLISHER
	Chapters 1-5	
Gager	Fundamentals of Botany	Blakiston
Sinnott	Botany, Principles and Problems	McGraw Hill
Transeau	General Botany	World Book
Coulter	Plant Relations	Appleton
Smallwood	Man — the Animal	Macmillan
Woodruff	Foundations of Botany	Macmillan
Cockerell	Zoölogy	World Book

AUTHOR	TITLE	PUBLISHER
Snyder	Chemistry of Plants and Animals	Macmillan
Stiles	Human Physiology	Saunders
	Chapters 6-15	
Fabre, J. Henri	Bramble — Bees and Others	Dodd
Fabre, J. Henri	Hunting Wasps	Dodd
Fabre, J. Henri	Life of the Caterpillar	Dodd
Fabre, J. Henri	Life of the Fly	Dodd
Fabre, J. Henri	Life of the Spider	Dodd
Fabre, J. Henri	The Mason-Bees	Dodd
Fabre, J. Henri	Insect Life	Macmillan
Fabre, J. Henri	Life and Love of the Insect	Macmillan
Fabre, J. Henri	Social Life in the Insect World	Century
Crary	Field Zoölogy	Out of print
Hewitt	House Fly	Macmillan
Hodge	Nature Study and Life	Ginn
Howard	House Fly. Disease Carriers	Ohio State Dept. Health
Kellogg	Animals and Man	Out of print
Ross	Reduction of Domestic Mosquitoes	Lippman
Smith	Our Insect Friends and Enemies	Lippman
Langstroth	Hive and Honey Bee	Amer. Bee Society
Lutz	Field Book of Insects	Putnam
Mitchell	Mosquito Life	Out of print
Osborn	Economic Zoölogy	Macmillan
Phillips	Bee Keeping	Macmillan
Root	A.B.C. and X.Y.Z. of Bee Culture	Root
Wheeler	Ants, Their Structure, Development, and Behavior	Columbia Un.
Calkins	Biology	Holt
Jordan, Kellogg & Heath	Animal Studies	Appleton
Pearse	General Zoölogy	Holt
Smallwood	Textbook of Biology	Macmillan
Herrick	American Lobster: Study of Habits and Development	U. S. Fish. Bul.
Fabre	Insect Adventures	Dodd
Herrick	Insects Injurious to the Household and Annoying to Man	American Book
Doane	Common Pests	Thomas Publishing
Comstock	Handbook of Nature Study	Comstock Publishing
Harris	Salmon and Trout	Macmillan
Henshall	Bass, Pike, Perch, and Others	Macmillan
Jordan	Fishes	Appleton
Jordan & Evermann	American Food and Game Fishes	Out of print
Dickerson	The Frog Book	Out of print
Hodge	Nature Study and Life	Ginn
Holmes	Biology of the Frog	Macmillan
Marshall	The Frog	Macmillan
Morgan	Embryology of the Frog	Out of print
Ditmars	Reptile Book	Doubleday
Linville & Kelly	General Zoölogy	Ginn
Reese	Alligator and Its Allies	Putnam
Reese	Alligators as Food	Out of print
Chapman	Handbook of Birds of Eastern N.A.	Appleton
Hoffman	Birds of the Pacific Coast	Out of print
Bailey	Birds of New Mexico	Out of print
Allen, Fuertes & Pirnie	Lab. Notebook for Intensive Bird Study	Comstock
Baynos	Wild Bird Guests	Dutton
Forbush	Useful Birds and Their Protection	Out of print
Thomson	Biology of Birds	Macmillan
Anthony	Field Book of N. A. Mammals	Putnam

AUTHOR	TITLE	PUBLISHER
Ashbrook	Fur Farming for Profit	Out of print
Davenport	Domestic Animals and Plants	Out of print
Plumb	Types and Breeds of Farm Animals	Ginn
Stone & Cram	American Animals	Stone Publishing
Warren	The Beaver: Its Works and Ways	Williams & Wilkins
Galloway	First Course in Zoölogy	Blakiston
Hegner	Introduction to Zoölogy	Macmillan
Jordan & Kellogg	Animal Life	Appleton
Chapters 16-25		
Curlis	Science and Human Affairs	Out of print
Judd	Psychology of Social Institutions	Macmillan
Osborn	Men of the Old Stone Age	Scribner
Smallwood	Man, the Animal	Macmillan
Cutten	Psychology of Alcoholism	Scribner
Davenport	Heredity in Relation to Eugenics	Holt
Guyer	Being Well-Born	The Bobbs-Merrill Company
Harsley & Sturge	Alcoholism and the Human Heart	
Conn	Biology	Silver
Conn	Story of Germ Life	Out of print
Frankland	Our Secret Friends and Foes	Out of print
Prudden	Story of Bacteria	Putnam
Celli-Eyre	Malaria	Out of print
Chalmers	The Beloved Physician, Dr. E. L. Trudeau	Houghton
Chapin	Sources and Modes of Infection	Wiley
Conn	Bacteria in Mills	Out of print
Cornell	Health and Medical Inspection of School	Davis, S. A. Co.
U. S. Bulletin 56	Hygienic Laboratory Bulletin	
Vallery-Radot	The Life of Pasteur	Doubleday
Woodhead	Bacteria and Their Products	Scribner
Edelman, Mehler & Eich.	Meat Inspection	Lea and Febiger
Knoff	Tuberculosis, Present and Current Disease	Out of print
Rosenaw	Disinfections and Disinfectants	Appleton
Stiles	Prev. & Geog. Distribut. of Hookworm Disease	Out of print
Trudeau	An Autobiography	Doubleday
Bergen & Caldwell	Introduction to Botany	Ginn
Bergen & Caldwell	Practical Botany	Ginn
Bergen & Davis	Principles of Botany	Ginn
Conn	Biology	Silver
Cook	College Botany	Lippman
Coulter, Barnes, Cowles	Textbook of Botany	Am. Book
Curtis	Nature and Develop. of Plants	Holt
Gibson	Sharp Eyes	Grosset and Dunlap
Holman & Robbins	Textbook of General Botany	Wiley
Smith & Others	Textbook of General Botany	Macmillan
Snyder	General Science	Allyn & Bacon
Coulter	Plant Life and Plant Uses	Appleton
Conn	Story of Germ Life	D. Appleton
Weaver	Root Development of Field Crops	McGraw
Weaver & Bruner	Root Development of Veg. Crops	McGraw
Bessey	College Botany	Holt
Hough	American Woods	Out of print
Keeler	Handbook of Trees	Houghton
Moon	Book of Forestry	Appleton
Robbins and Rickett	Botany	D. Van Nostrand
Sargent	Trees of N. A.	Houghton
Schenck	Forestry Policy	Out of print

GLOSSARY

A

ABDO'MEN (Lat. *abdomen*, belly): the third region of an insect's body; the region between the chest and the hips in man.

ABSORP'TION (Lat. *absorbere*, to swallow down): the process of taking in liquid food or other substances through the walls of cells.

ACCES'SORY (Lat. *accedo*, give to) BUDS: more than the normal number (one) in the axil of a leaf. Accessory parts of a flower are the sepals and petals.

ACQUIRED IMMU'NITY: that which results from having had a disease, or from preventive measures.

ADAPTA'TION (Lat. *adaptare*, to fit): changes in, or peculiarities of organisms which make them fit for their environment; fitness.

AD'ENOIDS (Gk. *aden*, gland): fleshy growths in the cavity back of the nose.

ADUL'TERATE (Lat. *ad*, to, + *alter*, other): to add a cheap or inferior substance to a good one; to cheapen, weaken, or reduce.

ADVENTI'TIOUS (Lat. *ad*, to, + *venio*, come): appearing at unusual places, as roots on a slip.

AE'DES CAL'OPUS: a mosquito, the female of which carries yellow fever.

AF'FERENT (Lat. *ad*, to, + *fero*, bear) FIBERS: those which convey impulses to the sense organs, brain, or spinal cord.

AGGRES'SIVE (Lat. *ad*, to, + *gradior*, walk) COLORATION: that which conceals an organism as it lies in wait for prey.

AKENE' (Gk. *a*, not, + *chainein*, to gape): a dry, indehiscent fruit, as in buttercup, dandelion, and clematis.

ALBU'MEN: white of egg.

AL'COHOL: a narcotic poison; the intoxicating element in whisky, beer, wine, etc.

ALIMEN'TARY (Lat. *alimentum*, food) CANAL: the digestive tube or tract.

AL'KALINE SUBSTANCE: one which neutralizes an acid.

ALTRI'CIAL (Lat. *altrix*, nurse) BIRDS: those that are helpless when hatched, as robins, sparrows, etc.

AMPHIB'IANs (Gk. *amphi*, double, + *bios*, life): animals that spend part of their life in water and part on land, as a frog.

AMPHIOX'US (Gk. *amphi*, double, + *oxys*, sharp): a small, burrowing, spindle-shaped marine animal; a possible ancestor of vertebrates.

AMYLOP'SIN (Gk. *amylon*, starch): an enzyme found in the pancreatic juice that changes starch to sugar (glucose).

ANÆSTHET'IC (Gk. *an*, not, + *aisthesis*, feeling): a substance that destroys consciousness.

AN'GIOSPERM (Gk. *angeion*, a case, + *sperma*, a seed): a plant which bears its seeds in a case, as pea, bean, poppy.

ANNEL'LIDA (Gk. *anulus*, ring): a group of worms composed of rings or segments, as earthworm and sand worm.

AN'NUAL (Lat. *annus*, year) RING: the concentric growths of light and dark cells formed in a woody stem during a year.

ANOPH'ELES: the kind of mosquito that carries the malarial parasite.

ANTEN'NA (Lat. *antenna*, a sailyard): a jointed sensory organ on the heads of insects, crabs, etc.

ANTE'RIOR (Lat. *ante*, before): nearer the head (zoölogy); facing outward from the axis (botany).

AN'THER (Gk. *antheros*, flowery): the pollen-bearing part of a stamen.

ANTISEP'TIC (Gk. *anti*, against, + *sepsis*, putrefaction): a substance which prevents the growth of bacteria or other organisms.

ANTITOX'IN (Gk. *anti*, against, + *toxin*, a poison): a substance in the blood after certain diseases which confers immunity from further attacks for a greater or lesser period.

ANUS (Lat. *anus*, ring): the posterior opening of the alimentary canal.

AOR'TA (Gk. *aorte*, from *aeirein*, to lift): the largest artery in the body; the one leaving the left ventricle.

AP'IARY (Lat. *apis*, bee): a place where bees are kept.

APPEN'DAGE (Lat. *ad*, to, + *pendo*, hang): an organ, usually jointed, attached to the body.

A'QUEOUS (Lat. *aqua*, water) HUMOR: the transparent liquid in the front part of the eye.

ARACH'NIDA (Gk. *arachne*, a spider): a class of arthropods which includes spiders, scorpions, mites, etc.

AR'TERY (Lat. *arteria*, an artery): a blood vessel that carries blood away from the heart.

ARTHROP'ODA (Gk. *arthron*, joint, + *pod* (root of *pous*), foot): a group of animals having jointed legs, as insects, crayfish, and spiders.

ARTICULA'TION (Lat. *articulo*, divide into joints): the joining or place of meeting of two bones.

ARTIFI'CIAL BREATHING (artificial respiration): that produced by mechanical means in an attempt to resuscitate drowned persons or those suffocated by gas.

ASEX'UAL: without sex; reproduction by other means than egg and sperm.

ASH: the grayish mineral substance resulting from the burning of organic matter, as wood.

ASSIMILA'TION (Lat. *assimulare*, to make like): the process of changing digested food or stored materials into protoplasm.

ASTIG'MATISM (Gk. *a*, without, + *stigma*, spot): a defect in the curvature of the lens of the eye which causes indistinct vision.

AU'RICLES (Lat. *auricula*, little ear): the upper chambers of a vertebrate heart.

AX'ILLARY (Lat. *axilla*, dim. of *axis*, axis) **BUDS**: those which arise in the angle between the stem and the leaf.

B

BACIL'LUS (Lat. *bacillum*, little stick): a rod-shaped bacterium.

BACTE'RIA (Gk. *bacteron*, a stick): the smallest and simplest plants.

BALANCED AQUARIUM: one in which plant life and animal life supply each other's needs.

BALANCED DIET: one in which there are the correct amounts of carbohydrates, proteins, fats, mineral salts, and vitamins.

BALL-AND-SOCKET JOINT: one in which the enlarged end of one bone fits into a depression in another, allowing free motion.

BAST: tough fibers in the inner bark of trees and other plants; part of the phloëm.

BEE'TLE: an insect having hard wing covers; one of the Coleoptera.

BELLY OF MUSCLE: the middle portion of a muscle.

BIEN'NIAL (Lat. *bi*, two, + *annus*, year): a plant which grows and stores food the first year and bears fruit the second year.

BILE: the fluid secreted by the liver.

BIOLOGICAL DISEASES: those caused by living organisms.

BIOL'OGY (Gk. *bios*, life, + *logos*, a talk or discourse): the study of living things.

BI'VALVE (Lat. *bi*, two, + *valva*, leaf of a door): a mollusk having two valves or shells, as a clam or oyster.

BLADDER: the muscular sac in which urine collects.

BLADE: the expanded portion of a leaf.

BLAS'TULA (Gk. *blastos*, a bud): the hollow-sphere stage in the development of certain eggs.

BLIGHT: disease of plants caused by certain fungi.

BODY CAVITY: the space in which the vital organs are contained.

BRACT (Lat. *bractea*, a thin metal plate): a small, leaf-like growth at the base of the pedicel of a flower.

BRAIN: the compact anterior portion of the nervous system; in vertebrates, the part inclosed in the skull.

BRONCHUS, pl. *bronchi* (Gk. *bronchos*, windpipe); one of the two large subdivisions of the trachea.

BUD: an undeveloped branch or flower; an outgrowth on sponge, hydra, and yeast.

BUDDING: a form of grafting; the insertion of a bud of one tree under the bark of another.

BULB: a cluster of thickened leaf-bases attached to a reduced stem, and surrounding a bud, as in onion, hyacinth, etc.

BY-PRODUCT: a product of minor importance in a manufacturing process, as oxygen in photosynthesis.

C

CAL'ORIE (Lat. *calere*, to be hot): a unit employed in estimating the kind and amount of food necessary to maintain the body at its best. It is the amount of heat required to raise one kilogram of water one degree centigrade.

CA'LYX (Greek, *kalyx*, cover): the outermost row of leaves or parts of a flower, usually green.

CAM'BIUM (Lat. *cambire*, to exchange): the active, growing cells between the xylem and the phloëm in the fibrovascular bundles of dicotyledonous plants.

CAP'ILLARY (Lat. *capillus*, a hair): the microscopic blood vessels which occupy the spaces between the ends of arteries and the beginnings of veins.

CAR'APACE (Sp. *carapacho*, a covering): the shell-like dorsal covering of crustaceans and turtles.

CARBOHY'DRATE (Lat. *carbo*, coal; Gk. *hydor*, water): the class of food-stuffs made of carbon, hydrogen, and oxygen, the hydrogen and oxygen being in the same proportion as in water.

CARBON DIOX'IDE (Lat. *carbo*, coal; Gk. *di*, two; *oxys*, acid): a gas formed as a waste product of oxidation in both plants and animals.

CARNIV'OROUS (Lat. *caro* (*carnis*), flesh; *vovare*, to eat): flesh-eating.

CAR'RIER: a person, or animal, immune to certain bacterial diseases but capable of infecting others with bacteria from his body.

CAR'TILAGE (Lat. *cartilago*, gristle): the elastic animal tissue forming parts of organs or bones.

CA'SEIN (Lat. *caseus*, cheese): the form of protein found in the curd of milk.

CAT'ERPILLAR (Lat. *catta*, cat; *pilus*, hair): the active, larval stage in the metamorphosis of a flying insect.

CAUD'AL (Lat. *cauda*, tail): pertaining to the tail.

CELL (Lat. *cella*, a small room): the unit of structure and function of living things. A mass of protoplasm inclosing a nucleus, and usually inclosed by a cell wall.

CELLULOSE (Lat. *cellula*, a little cell): an organic substance usually found in the walls of plant cells.

CEN'TIPEDE (Lat. *centum*, one hundred; *ped*, root of *pes*, foot): a small arthropod having two legs on each segment.

CERE (Lat. *cera*, wax): a fleshy growth at the base of the bill of some birds.

CEREBEL'LUM (Lat. *cerebellum*, little brain): the part of the brain behind the cerebrum in man, and overlying the midbrain.

CER'EBRUM (Lat. *cerebrum*, the brain): the front part of the brain.

CHAR'ACTER (Gk. *charakter*, an engraved mark or stamp): a trait or structure passed on from parent to offspring. Characters may be *dominant*, or *recessive* (which see).

CHELA (Gk. *chele*, claw): the large pincer of a crayfish or lobster.

CHIROP'TERA (Gk. *cheir*, hand, + *pteron*, wing): the "hand-winged" mammals, as bats.

CHITIN (Gk. *chiton*, a gown or tunic): the outer covering of the bodies of some animals, as insects.

CHLO'ROPHYLL (Gk. *chloros*, green, + *phyllos*, leaf): the green coloring matter characteristic of plants; the substance in which photosynthesis takes place.

CHLO'ROPLAST (Gk. *chloros*, green, + *plastos*, molded): the granules in the protoplasm of a cell which contain chlorophyll.

CHRY'S'ALIS (Gk. *chrysos*, gold): the quiescent stage in the development of a moth or butterfly; the pupa inclosed in a thin, smooth case.

CIL'IUM (Lat. *cilium*, an eyelid with eyelashes): a tiny hair-like projection of cytoplasm attached to some portion of the surface of a cell.

CLAV'ICLE (Lat. *clavicula*, a little key): the collar bone, so named from its shape.

CLEISTOG'AMOUS (Gk. *kleistos*, closed, + *gamos*, marriage) FLOWERS: those which usually appear below the surface and are specially modified for self-fertilization. Violets produce cleistogamous flowers after the others.

CLOA'CA (Lat. *cloaca*, sewer): the lower end of the digestive tract which receives also wastes from the kidneys and the reproductive products in some vertebrates, as frogs and birds; the central cavity of a sponge.

COAL: a substance used for fuel, consisting largely of carbon formed from the remains of ancient vegetation.

COC'CUS (Gk. *kokkus*, berry): a spherical bacterium.

COCOON' (Lat. *concha*, shell): the hairy or silken covering of the pupa of some insects; the egg case of spiders and earthworms.

CÆ'LOM (Gk. *koilos*, hollow): the body cavity; the part of the body in which the organs lie.

COLEOP'TERA (Gk. *coleos*, sheath, + *pteron*, wing): an order of insects having hard wing covers over the flying or true wings; the beetles.

COMMUNICABLE (Lat. *communico*, hold in common) DISEASES: those which can be given by one person or animal to another. True of certain biological diseases, as diphtheria, or foul brood in bees.

COMPOUND EYES (Lat. *compono*, put together): an eye made up of many separate facets or parts, as in insects and crayfish.

CONJUGATION (Lat. *con*, with, + *jugare*, to join): the temporary union of two similar cells for the purpose of exchanging nuclear protoplasm, as in paramecium.

CONSERVATION OF ENERGY: Energy can be neither created nor destroyed. Any given amount may be made to assume different forms, as heat, light, motion.

CONSERVATION OF MATTER: Matter can be neither created nor destroyed. Its form may be changed, as in water, which may exist as a gas, a liquid, or a solid; wood may be burned, *i.e.* changed into water, smoke, and ashes.

CONTRACTILE VACUOLE: a cell organ found in many Protozoa, which appears and disappears regularly.

CORM (Gk. *kormos*, tree trunk): a solid, underground stem for storage of food, as in jack-in-the-pulpit.

COROLLA (Lat. *corolla*, crown): the petals of a flower taken together.

CORPUSCLE (Lat. *corpusculum*, a little body): the floating cells in the blood, red and white.

CORTEX (Lat. *cortex*, bark): the fleshy portion of a root surrounding the central cylinder and covered by epidermis.

CORYMB (Gk. *korymbos*, top): a flat-topped or rounded (convex) flower cluster.

COTYLEDON (Gk. *kotyledon*, a socket): the seed leaf of a plant. Monocotyledonous plants have only one, dicotyledonous plants have two.

CROSS-FERTILIZATION: the union of the nuclei of the egg of one individual and the sperm of another.

CROSS-POLLINATION: the receiving of pollen from a different plant by the pistil.

CRUSTACEA (Lat. *crusta*, a crust): a group of animals covered with a hard exoskeleton, as crayfish.

CULEX: the scientific name of a very common, non-disease-bearing mosquito.

CULTURE: a controlled growth of bacteria, fungi, or Protozoa, usually in a prepared nutrient medium. A pure culture contains only one kind of organism.

CUTIN (Lat. *cutis*, skin): the transparent waxy covering of leaves.

CYTOPLASM (Gk. *kytos*, vessel, + *plasma*, anything formed): the form of protoplasm which makes up the main part of a cell. It incloses the nucleus, and is inclosed by the cell wall.

D

DECID'UOUS (Lat. *de*, down, + *cado*, fall) **LEAVES**: those which fall from the tree in autumn.

DECOMPOS'ITION (Lat. *de*, from, + *cum* (com), together, + *ponere*, to place): the act of separating into constituent parts; decay or rotting.

DEHIS'CENT (Lat. *de*, from, + *hiscere*, to open): a term applied to fruits that open, as pod, capsule, etc.

DELIQUES'CENT (Lat. *deliquescere*, to melt or dissolve): a term applied to trees, the trunks of which subdivide repeatedly.

DEMONSTRA'TION (Lat. *de*, fully, + *monstro*, show): an orderly sequence of events, repeated by some one who wishes to explain or illustrate certain facts to learners. In a demonstration, the facts are already known. In an experiment, they are not known.

DEN'TINE (Lat. *den(ti)s*, a tooth): the inner portion of a tooth.

DEO'DORIZER (Lat. *de*, from, + *odor*, smell): a substance used to modify or disguise odors.

DERMIS (Gk. *derma*, skin): the true skin, lying beneath the epidermis.

DI'APHRAGM (Gk. *diaphragma*, a partition wall): the sheet of muscle which separates the chest cavity from the abdomen.

DI'ASTASE (Gk. *diastasis*, separation): the enzyme or ferment in plants which converts starch to grape sugar (glucose).

DICOTYLE'DON (Gk. *di*, two, + *kotyledon*, a socket): a plant which bears seeds having two cotyledons, as bean.

DIGES'TION (Lat. *digestio*, the dissolving of food): the process of preparing food for absorption.

DIP'TERA (Gk. *di*, twice, + *pteron*, wing): an order of insects which have only two wings, as fly and mosquito.

DISC (Gk. *discus*, a disc) **FLOWERS**: the central portion of certain "flowers" like the daisy or sunflower.

DISINFECT'ANT (Lat. *dis*, apart, + *inficio*, make): a substance used to destroy harmful bacteria.

DOMINANT (Lat. *dominare*, to rule) **CHARACTERS**: those which are present in the hybrid.

DOR'MANCY (Lat. *dormio*, sleep): the state of quiescence characteristic of seeds before germination.

DOR'SAL (Lat. *dorsum*, the back): pertaining to the back.

DRONE: the male of bees and ants.

DRY FARMING: the raising of crops in semi-arid regions.

DRY FRUITS: not fleshy. Nuts, cereals, pods, etc.

DUCTLESS GLANDS: those which pour their secretions directly into the blood, as thymus and adrenal glands.

E

EC'TODERM (Gk. *ectos*, outside, + *derma*, skin): the outer layer of cells of animals.

EC'TOPLASM (Gk. *ectos*, outside, + *plasma*, thing molded): the outside layer of unicellular organisms.

EDENTA'TA (Lat. *e*, out, + *den(ti)s*, tooth): a group of mammals which have no teeth.

EF'FERENT (Lat. *e*, out, + *fero*, bear) FIBERS: the fibers that carry impulses away from the brain, the motor fibers.

EGG: the female element in sexual reproduction; the ovum.

EL'EMENT (Lat. *elementum*, first principle): a substance which cannot be further simplified by chemical means; one of the simple substances which, combined with others, make up the objects around us, both organic and inorganic.

EM'BRYO (Gk. *embryon*, an embryo): an organism in its early stages of development.

EMBRYOL'OGY (Gk. *embryon*, an embryo, + *logos*, a talk or discourse): the study of the early development of organisms.

ENAM'EL: the hard outer covering of the upper part of the teeth.

ENCYST'MENT (Gk. *en*, in, + *kystis*, a bladder): the act of being inclosed in a resistant covering; forming a cyst.

EN'DODERM (Gk. *endon*, within, + *derma*, skin): the inner layer of cells in sponge, hydra, or an embryo.

EN'DOPLASM (Gk. *endon*, within, + *plasma*, substance): the inner portion of the protoplasm in a one-celled animal.

ENDOSKEL'ETON (Gk. *endon*, within, + *skeleton*, a dried body): a skeleton within the body, as in man, frog, fish.

EN'DOSPERM (Gk. *endon*, within, + *sperma*, a seed): the food that is stored near the embryo, as in a grain of corn.

EN'ERGY (Gk. *energos*, at work): the power to perform work.

ENTOMOL'OGIST (Gk. *entomon*, insect, + *logis*, talk or discourse): a person who studies insects.

ENVI'RONMENT (Fr. *environ*, around): the surroundings of an organism, such as air, water, temperature, etc.

EN'ZYME (Gk. *en*, in, + *zyme*, leaven): a substance secreted by certain organisms and inducing chemical changes, as digestion or fermentation.

EPHEMER'IDA (Gk. *ephmeros*, for a day): an order of insects which live but a few hours.

EPIDEM'IC (Gk. *epi*, upon, + *demos*, the people): a disease that is widespread, affecting many people or many plants or animals at the same time.

EPIDER'MIS (Gk. *epi*, upon, + *derma*, skin): the covering of the true skin; the outer layer.

EPIGLOT'TIS (Gk. *epi*, upon, + *glottis*, glottis): the lid which closes the opening into the trachea when anything is swallowed.

ERO'SION (Lat. *erodere*, to gnaw off): the wearing away of a substance, especially soil, by the action of the natural elements, as wind or water.

ESOPHAGUS (Gk. *oiso*, will bear, + *phagein*, to eat): the tube through which the food passes from the pharynx to the stomach; the gullet.

ESSEN'TIAL PARTS (of a flower): the stamens and pistils, both of which are necessary in forming a seed.

EUGEN'ICS (Gk. *eugenes*, well born): the study of heredity in its relation to the improvement of offspring.

EUSTA'CHIAN TUBES: the tubes which connect the middle ear with the throat. Named for *Eustachio*.

EVERGREENS: plants which retain their leaves for several years, the cone-bearing trees, in general.

EXCRE'TION (Lat. *excretus*, separated out): the process of removing waste products from the protoplasm; the products so removed.

EXCUR'RENT (Lat. *ex*, out, + *currere*, to run) STEM: a stem which extends from base to tip without dividing, as spruce, cedar, etc.

EXHAL'ANT (Lat. *ex*, out, + *halo*, breathe) PORE: the central opening at the top of a sponge through which water is passed outward.

EXOSKEL'ETON (Gk. *exo*, outside, + *skeleton*, a dried body): the outer, crustaceous or horny covering of animals, as crayfish, lobsters, and insects.

EXPER'IMENT (Lat. *experior*, try): a test under controlled conditions for the purpose of discovering new facts, truths, or relations. In a real experiment, the result is not known beforehand. As a verb: to test under controlled conditions, etc.

EXPIRA'TION (Lat. *ex*, out, + *spiro*, breathe): the process of emptying the lungs of air in breathing.

EXTEN'SORS (Lat. *ex*, out, + *tendo*, stretch): the muscles which straighten an appendage at the joint.

F

FANGS: the organs through which spiders, snakes, and other animals inject poison or venom into their prey or enemies.

FAS'CICLED (Lat. *fasciculus*, a little bundle) ROOTS: the clustered, fleshy roots of dahlia and other plants.

FATIGUE' (Lat. *fatigo*, tire): the effect of exertion or other stimulation of cells or organs.

FATS: one of the common classes of nutrients, containing much carbon and hydrogen and little oxygen.

FEATHERS: the characteristic covering of birds.

FE'CES (Lat. *fæces*, dregs): indigestible material in the alimentary canal; excrement.

FEELERS: antennæ; the long, slender, jointed projections from the head found chiefly in crustaceans.

FEHLING'S SOLUTION: a substance used to determine the presence of glucose or grape sugar. Several formulas are in common use.

FE'MUR: the upper bone of the lower limb in vertebrates; the large portion of the leg of a grasshopper.

FER'MENT: an enzyme; a substance which produces fermentation.

FERTILIZA'TION (Lat. *fertilis*, from *fero*, bear): the union of the sperm nucleus with the egg nucleus in forming a new individual or organism.

FER'TILIZER: a substance added to the soil to promote plant growth.

FIBRIN'OGEN (Fr. *fibre*, a fiber): the substance in the blood which induces clotting by the production of fibers when exposed to air.

FI'BROUS (Fr. *fibre*, a fiber) **ROOTS:** those composed of many slender fibers, as in grass.

FIBROVAS'CULAR BUNDLES: the conductive system of plants. A fibrovascular bundle consists of xylem cells which communicate by means of perforations in the sides of their thick walls, and phloëm cells which are thin-walled and perforated at the ends. Other cells, non-conductive, are found in or near the bundle.

FIL'AMENT (Lat. *filum*, thread): the slender stalk of a stamen; any thread-like projection.

FIN: a locomotor organ characteristic of fishes and used for locomotion, balancing, and steering.

FIS'SION (Lat. *findere*, to split): division into two smaller cells by a process of splitting or pinching in two.

FLAC'CID (Lat. *flaccus*, flabby): a soft or relaxed condition of a cell due usually to shortage of water.

FLAGELL'UM (Lat. *flagellum*, a whip): a long cytoplasmic projection, used chiefly for locomotion.

FLATWORMS: a group of unsegmented worms, many of which are parasitic, as liver fluke and tapeworm.

FLESHY FRUITS: those that have the seeds surrounded by an edible, juicy layer, as pome (apple), drupe (plum).

FLEX'ORS (Lat. *flexus* (*flecto*), bend): muscles that bend the joints, that work in opposition to *extensors*.

FLIPPER: the fore limb of a seal or other aquatic mammal, modified as a swimming organ.

FLOWER: the organ of a plant which produces fruit containing seeds; or one of the essential parts of such an organ, as staminate flowers of corn, pistillate flowers of willow.

FOOD: a substance that furnishes material for the growth or repair of an organism, or that yields energy for it.

FORESTRY: the study and practice of producing successive crops of trees from a given tract.

FOSSILS: the stone-like remains of plants and animals no longer living on the earth.

FRUIT: the ripened ovary and its contents. In some fruits traces of other parts of the flower may be seen adhering to them.

FRY: young fishes just able to take care of themselves.

FUNC'TION (Lat. *functio*, performance): the normal action of any organ or set of organs; use.

FUNDAMENT'AL FUNC'TIONS: those on which an organism depends for existence, as respiration, excretion, etc.

FUN'GUS (Lat. *fungus*, mushroom): a plant which lacks chlorophyll. Fungi are dependent on prepared (organic) food, dead or alive.

G

GALL (Lat. *galla*, gallnut): a growth produced on certain leaves by the action of insects; the bile, a secretion of the liver.

GALL BLADDER: the sac in which gall or bile is stored temporarily.

GAN'GLION (Gk. *ganglion*, tumor): a collection of nerve cells.

GAS: one of the forms in which matter exists, as oxygen, hydrogen.

GAS'TRIC (Gk. *gaster*, stomach): pertaining to the stomach, as gastric glands.

GAS'TRULA (Gk. *gaster*, stomach): the two-layered stage in the development of an egg into an embryo.

GENERA'TION (Lat. *generatus*, from *genero*, beget): the persons existing at one time or period. Applied also to plants and animals.

GE'NUS (Lat. *genero*, beget): a group of organisms including one or more species. Used in classifying plants and animals.

GERM (Lat. *germen*, sprig): a microörganism; the rudimentary vital element; an embryo.

GERMINA'TION (Lat. *germinatus*, from *germino*, sprout): the beginning of growth of a seed or pollen. The term is commonly used to describe the growth of a plant from a seed. It more properly describes the growth of the embryo within the seed.

GILL RAKERS: projections on the gill arches of some fishes to assist in gathering food.

GILL SLITS: openings in the neck through which water, taken into the mouth, passes out over the gills, as in fishes.

GILLS: thin, finely divided organs of aquatic vertebrates, used to gather oxygen; also present in crayfish.

GIR'DLE: the bones which attach vertebrate limbs to the axial skeleton (the anterior is called the *pectoral* and the posterior the *pelvic* girdle); to encircle with a deep cut or by removing the bark, as to girdle a tree.

GIZ'ZARD (Lat. *gigeria*, cooked entrails of poultry): the muscular chamber where food is ground. A characteristic organ of birds.

GLAND: an organ which produces a substance for use in the body, or for removal from it; examples, salivary gland, kidney.

GLOMER'ULUS (Lat. *glomero*, make a ball): minute rounded bodies in the cortex of a kidney; a knot of blood vessels; a Malpighian body.

GLOT'TIS (Gk. *glotta*, tongue): the opening into the trachea.

GLU'COSE (Gk. *glykys*, sweet): the form of sugar found in fruits; the product of the digestion of starch.

GLU'TEN (Lat. *gluten*, glue): the proteid substance in cereals which makes them sticky when wet and crushed.

GLYC'ERIN (Gk. *glykeros*, sweet, from *glykys*): the sweet substance resulting from the digestion of natural fats.

GLY'COGEN (Gk. *glykys*, sweet, + *gen*, producing): animal starch, stored in the liver.

GON'AD: a sex organ, either male or female.

GON'IUM: a very small animal which consists of a colonial group of 16 cells, each practically independent.

GRAFT'ING: the process of inserting a small piece (twig) of one plant (the scion) into a slit in a larger one (the stock) and protecting it till the parts grow together.

GRAIN (Lat. *granum*, grain): one of the cereals, or cereals in general; a kernel of corn; the markings on wood due to annual rings and medullary (wood) rays.

GRAV'EL: small stones or pebbles, usually rounded and often mixed with sand.

GRAV'ITY (Lat. *gravis*, heavy): the force which tends to draw objects towards the center of the earth.

GREEN GLANDS: excretory organs of a crayfish, found in the head region.

GREEN MANURING: the process of plowing under a crop of some leguminous plant, as clover, for the sake of the nitrogen which has been gathered by bacteria living on its roots.

GRUB: the larva of certain beetles, as white grub, the larva of the May beetle.

H

HAB'IT (Lat. *habitus*, condition): a tendency towards an action or condition which, by repetition, has become spontaneous.

HAB'ITAT (Lat. *habito*, inhabit): the region where any organism or group of organisms is usually found; the place where it lives.

HARD PAL'ATE: the bony part of the roof of the mouth.

HEAD: the division of the body which contains the brain; a collection of small flowers; the collection of grains which make up the fruit of cereals.

HEALTH: the condition resulting from the normal performance of all the life functions.

HEMIP'TERA (Gk. *hemi*, half, + *pteron*, wing): an order of insects which have the anterior part of their wings hard and the posterior part membranous.

HEMOGLO'BIN (Gk. *haima*, blood, + Lat. *globus*, globe): the red coloring matter in the small blood corpuscles.

HEM'ORRHAGE (Gk. *haima*, blood, + *rhegnymi*, break): the discharge of blood from a ruptured blood vessel.

HERBIV'OROUS (Lat. *herba*, grass, + *voro*, eat): animals which feed upon grass and other plants.

HERED'ITY (Lat. *heres*, heir): the passing on to offspring of characters of parents or other ancestors.

HIBERNA'TION (Lat. *hiems*, winter): the condition induced by severe cold in the case of some animals; a death-like torpor and rigidity brought about by extreme cold.

HI'LUM: the scar on a seed showing where it was attached to the fruit.

HINGE JOINT: one which admits only of back-and-forth motion, as the elbow.

HOMOP'TERA (Gk. *homos*, same, + *pteron*, wing): a group of insects having their wings of the same texture throughout, in contrast to the Hemiptera.

HON'EY: the partly digested food of bees. They suck up nectar which is retained in the crop till partially digested, after which it is pumped up and stored in cells of wax.

HOOK'WORM: a small parasitic, unsegmented, round worm found in the intestine of man, sheep, and other animals.

HOR'MONES (Gk. *hormaein*, to excite): substances secreted directly into the blood in one part of the body which are carried by the circulation and incite action in another part of the body; chemical messengers.

HOST (Lat. *hospes*, entertainer): the larger organism on or in which a smaller, dependent one (parasite) lives.

HU'MERUS (Lat. *humerus*, shoulder): the larger bone of the upper arm.

HU'MORS (Lat. *humere*, to be moist): the transparent liquids of the eyeball.

HU'MUS (Lat. *humus*, ground): the substances in the soil formed by the decay of organic matter; vegetable mold.

HY'BRID (Lat. *hybrida*, mongrel): the offspring of parents of two different species or varieties. The mule is a hybrid.

HY'DRA (Gk. *hydor*, water): a two-layered aquatic animal; a polyp.

HY'DROGEN (Gk. *hydor*, water, + *gen*, create): one of the two elements that enter into water; the lightest known substance.

HY'GIENE (Gk. *hygeia*, health): the study of health, especially as to maintaining health by observing proper conditions.

HYMENOP'TERA (Gk. *hymen*, a membrane, + *pteron*, wing): an order of insects (including bees and wasps) which have membranous wings.

HY'PHÆ (Gk. *hyphai*, a web): the single strands or threads which make up the body of a fungus.

HYPOCOT'YL (Gk. *hypo*, under, + *kotyledon*, socket): the part of a developing plant embryo which lies between the stem and the root.

HYPOPHAR'YNX (Gk. *hypo*, under, + *pharynx*, throat): the tongue-like organ of a grasshopper.

I

ICHNEU'MON (Gk. *ichneuo*, hunt): a hymenopterous insect which lays its eggs on the larvæ of other insects or in them; a helpful parasitic insect.

IMBECIL'ITY (Lat. *imbecillus*, weak): the state or condition of being far below normal in mental development; feeble-mindedness.

IMMU'NITY (Lat. *immunis*, free from duty): the condition which prevents a person from "taking" an infectious disease.

INCI'SOR (Lat. *incido*, cut into): a cutting tooth. In gnawing animals the incisors have chisel edges.

INCUR'RENT (Lat. *in*, in, + *curro*, run) SIPHON: the tube through which water enters the gill chamber of clams.

INDEF'INITE ANNUAL GROWTH: the forming of new wood throughout the whole growing season, as in sumac.

INDEHIS'CENT (Lat. *in*, not, + *dehiscere*, to open) FRUITS: those that do not open, as nut, grain of corn, akene.

INDETER'MINATE (Lat. *in*, not, + *de*, completely, + *termino*, terminate) INFLORES'CENCE (Lat. *in*, in, + *floreo*, bloom): a form of flowering in which the axis continues to grow and new flowers continue to form. A plantain illustrates it.

INFU'SION (Lat. *in*, in, + *fusus*, from *fundo*, pour): the process of steeping a substance in a liquid for the purpose of extracting its medicinal or other qualities; the liquid extract so obtained, as hay infusion.

INHAL'ANT (Lat. *in*, in, + *halo*, breathe) PORES: the mouths of tubes which conduct water inward through the walls of a simple sponge.

INOCULA'TION: the introduction of a virus, as of smallpox, into the system through the skin.

INORGAN'IC (Lat. *in*, not, + *organum*, organ) MATTER: that which has not been formed by living (organic) processes.

IN'SECT (Lat. *in*, in, + *sectum*, cut): a group of small animals having three distinctly marked-off body regions.

INSECTIV'ORA (Lat. *insectum*, insect, + *voro*, to eat): an order of insect-eating vertebrates, including moles and shrews.

INSER'TION (Lat. *insertus*, from *in*, in, + *sero*, join): the place of attachment of a muscle.

INSPIRA'TION (Lat. *in*, in, + *spiro*, breathe): the act of taking air into the lungs.

IN'SULIN: a treatment for diabetes.

INTEG'UMENT (Lat. *in*, in, + *tego*, cover): an outer covering or envelope, as the skin.

INTES'TINE (Lat. *intestinus*, internal): that portion of the alimentary canal in vertebrates between the stomach and the anus. There are two divisions or sections, the small intestine and the large intestine.

INVER'TEBRATES (Lat. *in*, not, + *vertere*, to turn): all animals which lack a vertebral column, as worms, insects, mollusks.

INVOL'UNTARY (Lat. *in*, not, + *voluntas*, from *volo*, will) MUSCLES: those which are not under the control of the will, as the muscles of the intestine.

I'ODINE (iodin): one of the elements. It is used as a test for the presence of starch, which it turns blue, also as an antiseptic and a preventive of goiter.

I'RIS (Gk. *iris*, rainbow): the colored portion of the eye.

IRRITABIL'ITY (Lat. *irritabilis*, from *irrito*, excite): the property of reacting to stimuli; a life function.

J

JELLYFISH: a soft, jelly-like animal related to hydra.

JOINT (Lat. *jungo*, join): the place where two bones meet; an articulation.

K

KEEL: the projection on the breastbone of birds for the attachment of muscles for moving the wings.

KID'NEY: an organ which filters waste products from the blood, chiefly urea and water.

KINET'IC (Gk. *kinein*, to move) ENERGY: that form of energy employed in producing motion.

L

LA'BIUM (Lat. *labium*, lip): the lower "lip" of a grasshopper's mouth.

LA'BRUM (Lat. *labrum*, lip): the upper "lip" of a grasshopper's mouth.

LAC'TEALS (Lat. *lac*, milk): the vessels which carry the absorbed fats from the intestine to the vein which receives it.

LAR'VA (Lat. *larva*, a ghost): the eating and growing stage in the complete metamorphosis of some insects, as moths and butterflies.

LAR'YNX (Gk. *larynx*, gullet): the portion of the trachea which contains the vocal cords; the voice box; "Adam's apple."

LA'TENT (Lat. *lateo*, lie hidden) ENERGY: that form of energy which, temporarily, is not at work, as in a tightly wound watch spring.

LAT'ERAL (Lat. *latus*, side) BUD: one which is on the side of a stem.

LAY'ERING: the covering of the nodes of a stem with dirt to induce it to produce roots; a means of propagating such plants as grape vines.

LEAF MOSA'IC: the arrangement of leaves to cover all spaces, as ivy on a wall.

LEATH'ER (A.-S. *lether*, leather): the skin of an animal when tanned or otherwise prepared for use.

LEGUMES' (Lat. *legere*, to gather): plants which have pods for fruits; the seeds of such plants, as peas, beans, etc.

LEGU'MIN: the protein substance found in seeds of the pulse (pea) family.

LEN'TICEL: an opening in bark for the admission of air.

LEPIDOP'TERA (Gk. *lepis*, scale, + *pteron*, wing): the order of insects characterized by scaly wings, as moths and butterflies.

LIFE CYCLE: the stages of development, maturity, and decline through which every organism passes.

LIFE FUNCTIONS: the various physical processes upon which the continuance of life depends; the vital processes, as digestion, respiration, etc.

LIG'AMENT (Lat. *ligare*, to bind): a band of tissue which binds one bone to another.

LIP'OID (Gk. *lipos*, fat, + *eikos*, like): a substance found in abundance in cells of the nervous system which is dissolved by anæsthetics and narcotics.

LIQ'UID (Lat. *liquere*, to be fluid): a form of matter in which the particles move easily upon one another, as water, and take the shape of the container.

LIV'ER: the largest organ of the body, a gland which secrets bile, stores glycogen, and performs other functions.

LOAM: a form of soil containing much humus (which see).

LOCOMO'TION (Lat. *locus*, place, + *motus*, fr. *moveo* move): moving from one place to another. In many animals locomotion is essential in food-getting.

LYMPH (Lat. *lympa*, clear water): the fluid resembling plasma which fills intercellular spaces. The watery substance in a blister is lymph.

LYMPHAT'IC (Lat. *lympa*, clear water): a vessel that conveys lymph; pertaining to lymph.

M

MAGGOT: the legless larva of a fly.

MAGNE'SIUM: one of the elements; a trace of it is found in protoplasm.

MALA'RIA (Lat. *malus*, bad, + *aër*, air): a biological disease caused by parasitic protozoans which live in the body of the mosquito known as *Anopheles* during part of their life history, and part in the blood of man to which they are transmitted by the bite of a mosquito.

MALES: individuals producing sperms.

MAM'MARY (Lat. *mamma*, breast) **GLANDS**: the milk-secreting glands which are characteristic of mammals.

MAN'DIBLE (Lat. *mandere*, to chew): the cutting part of the mouths of crustaceans.

MARSU'PIALS (Marsupialia) (Gk. *marsipion*, a little pouch): an order of mammals having a pouch in which the young are carried, as opossum, kangaroo.

MAXIL'LA (Lat. *maxilla*, jaw): one of the mouth-parts of crustaceans.

MAXIL'LIPED (Lat. *maxilla*, jaw, + *pes*, foot): an appendage near the mouth of a crustacean which assists in getting or passing food.

MEAS'URING WORMS: the larvæ of certain moths which move by looping their bodies.

MEDUL'LA (Lat. *medius*, middle) OBLONGA'TA: the posterior part of the brain, connecting it with the spinal cord.

MED'ULLARY (Lat. *medulla*, pith) RAYS: thin bundles of wood cells extending from the pith to or toward the cambium and from the cambium to or toward the center; wood rays.

MEN'DELISM: the laws of heredity announced by Gregor Mendel.

MER'ISTEM (Gk. *meristos*, divisible): the actively growing tissue found in the tips of roots and stems.

MES'ENTERY (Gk. *mesos*, middle, + *enteron*, intestine): a fold of tissue which suspends the intestine from the dorsal wall of the abdomen.

MESOGLE'A (Gk. *mesos*, middle, + *gloia*, glutinous substance): the middle, non-cellular layer of hydra.

MES'OPHYLL (Gk. *mesos*, middle, + *phyllon*, leaf): the middle portion of a leaf, consisting of irregular, loosely packed cells.

MESOTHO'RAX (Gk. *mesos*, middle, + *thorax*, thorax): the middle section of the thorax of an insect. It has one pair of wings and the second pair of legs on it.

METAMOR'PHOSIS (Gk. *meta*, beyond, + *morphe*, form): the passing of an organism through several changes of form, as butterfly, frog.

METATHO'RAX (Gk. *meta*, beyond, + *thorax*, thorax): the third division of an insect's thorax. It bears the last pair of legs and the second pair of wings, if there is a second pair.

MI'CROBE (Gk. *mikros*, small, + *bios*, life): a microscopic organism; a bacterium.

MI'CROPYLE (Gk. *mikros*, small, + *pyle*, gate): the opening in the testa of an ovule through which the pollen tube enters.

MID'RIB: the main vein or rib of a leaf.

MIGRA'TION (Lat. *migro*, move): the act of changing a dwelling place from one locality to another, as birds and salmon do.

MIL'DEW: a fungus which causes decay and disease.

MILT: the sperms of a fish.

MIM'ICRY (Gk. *mimikos*, imitative): resemblances of organisms in form or color to other objects, for protection.

MIX'TURE (Lat. *misceo*, mix): a combination of several ingredients in which each retains its own individuality.

MOL'ECULE (Lat. dim. of *moles*, mass): the smallest part of a substance that can exist without losing its identity.

MOL'LUSKS (Lat. *mollis*, soft): a group of animals having soft bodies, usually covered by one or two shells.

MOLT: to cast off, as skin in snakes, feathers in birds, skin in larvæ.

MONOCOTYLE'DON (Gk. *monos*, single, + *kotyledon*, socket): a plant which has only one cotyledon in its seeds, as corn.

MOSA'IC VISION: the image formed by the compound eye of an insect, each facet producing a part which fits in with others to make a complete picture.

MOTHS: insects resembling butterflies; small lepidopterous insects which infest wool, cloth, fur, etc.

MOTOR (Lat. *moveo*, move) **FIBERS**: nerve fibers which convey impulses from the brain to the muscles, producing motion.

MOVABLE JOINTS: those capable of motion; opposed to sutures, which are immovable joints.

MU'COUS (Lat. *mucus*, slime) **MEMBRANE**: the lining of the alimentary canal and respiratory tract.

MUCUS (Lat. *mucus*, slime): a slimy substance secreted by certain cells of the mucous membrane.

MULE (Lat. *mulus*, mule): the offspring of a horse and a donkey.

MUS'CLE: an organ made up of contractile fibers, the function of which is to produce motion.

MUSH'ROOM: a fleshy fungus, particularly the edible field mushroom with pink gills.

MYCE'LIUM (Gk. *myces*, mushroom): the (hyphal) threads which make up the body of a fungus.

MY'OSIN (Gk. *myo*, muscle): the protein which exists in muscle.

MYRIAP'ODA (Gk. *myrioi*, ten thousand, + *pous*, foot): a group of arthropods made up mostly of centipedes and millipedes.

N

NARCOT'IC (Gk. *narkotikos*, making numb): a substance which dissolves lipid, dulls the senses, and in sufficient quantity produces insensibility.

NAT'URAL IMMU'NITY: the state of not being able to "take" an infectious disease, even though one has neither had the disease nor been immunized by treatment.

NAT'URAL SELEC'TION: the survival of those organisms which are best adapted to live under certain conditions, and the perishing of those less well adapted.

NEC'TAR (Gk. *nectar*, drink of the gods): the sweet fluid secreted by nectar glands in a flower; the substance from which bees make honey.

NERVE FIBERS: the separate fibers of which a nerve is made up; the elongated processes of neurons (nerve cells).

NERVOUS SYSTEM: the system by means of which an animal becomes aware of its surroundings, and by which it adjusts itself to them; the co-ordinating system.

NET-VEINED LEAF: one in which the veins branch again and again, forming a network.

NIC'TITATING (Lat. *nictare*, to wink) MEMBRANE: a thin, almost transparent inner eyelid found in certain vertebrates, as frog, bird, cat.

NISSL BODIES: granules in the bodies of nerve cells which disappear when the cell has been subject to frequent and prolonged stimulation.

NI'TROGEN: one of the elements in the form of gas. Besides constituting about four fifths of the air, it is found in many organic substances, as protein.

NODE (Lat. *nodus*, knot): the point from which leaves and branches arise on a dicotyledonous stem, and from which leaves arise on a monocotyledonous stem.

NO'TOCHORD (Gk. *notos*, the back, + *chorde*, a string): an unsegmented rod of cartilage in the back of the embryos of vertebrates around which the spinal column develops, eventually replacing it.

NOUR'ISHMENT (Lat. *nutrio*, nurse or feed): that which sustains, or promotes growth in any way.

NUCEL'LUS (dim. of *nux*, nut): the tissue which fills the space not occupied by the embryo sac in an ovule.

NU'CLEUS (Lat. *nucleus*, a kernel): specialized protoplasm, part of which transmits heritable traits to offspring.

NUT: a dry, indehiscent fruit with a hard pericarp, as walnut, hazel nut.

NU'TRIENTS (Lat. *nutrio*, nurse or feed): foods, such as starch, sugars, proteins, edible fats, and mineral matter, which contain the necessary elements for keeping the body in repair and making it grow; food compounds.

NUTRI'TION (Lat. *nutrio*, nurse or feed): the process by which growth is promoted and repairs made in living organisms.

NYMPH: an immature form of an insect, as grasshopper, which has incomplete metamorphosis.

O

ODON'ATA (Gk. *odontos*, toothed): an order of insects including dragon flies and damsel flies.

OIL (Lat. *oleum*, oil): a liquid substance of organic origin, containing carbon, hydrogen, and oxygen, insoluble in water. A food substance (edible fat).

OLFAC'TORY (Lat. *oleo*, smell, + *facio*, make) NERVE: the nerve which connects the organ of smell with the brain.

OPER'CULUM (Lat. *operculum*, lid): the gill cover in fishes.

OPTIC (Gk. *optikos*, sight) NERVE: the nerve which conducts impulses from the retina to the brain.

OR'DER (Lat. *ordo*, order): in classification, a group of organisms made up of several similar families.

OR'GAN (Gk. *organon*, instrument): any part of a plant or animal which performs some definite function.

ORGAN'IC ASH: the mineral matter left after the complete burning of plant or animal substances.

ORGAN'IC SUBSTANCE: any substance made by plants or animals.

OR'GANISM (Gk. *organon*, instrument): a plant or an animal.

OR'IGIN (Lat. *orior*, rise): the attachment of a muscle nearest the center of the body.

ORTHOP'TERA (Gk. *orthos*, straight, + *pteron*, wing): a group of insects whose outer wings meet in a straight line in the middle of the back. It includes grasshoppers and crickets.

OSMO'SIS (Gk. *osmos*, pushing): the passing of soluble substances through a moist membrane, the greater movement of soluble substance being from a region of high concentration to a region of low concentration. However, the water always flows from the more dilute to the more concentrated solution faster than the opposite process takes place.

O'VARY (Lat. *ovum*, an egg): the organ in female animals and in plants which produces ova or eggs.

O'VIDUCT (Lat. *ovum*, egg, + *duco*, lead): the tube through which the eggs leave the body.

OVIPOS'ITOR (Lat. *ovum*, egg, + *pono*, place): the organ in insects by which eggs are thrust into a hard substance, as earth or wood.

O'VULE (Lat. *ovulum*, a little egg): the body, in plants, which contains the egg cell. In case the egg cell is fertilized, the ovule develops into a seed or a fruit, as a grain of corn.

O'VUM (Lat. *ovum*, egg): the sexual element produced by the female.

OXIDA'TION: the chemical union of oxygen with another substance.

OX'YGEN: a gas, one of the elements. It is very abundant in nature, existing in the air as O_2 and in combination with carbon and hydrogen and nitrogen to make sugars, starch, and protein.

P

PAL'ATE (Lat. *palatum*, palate): the roof of the mouth.

PALISADE' CELLS: a row of cells longer than wide lying just beneath the epidermis of leaves.

PAL'MATELY COM'POUND LEAVES: those in which the leaflets, five or more in number, arise from the top of the petiole.

PALP (Lat. *palpo*, stroke): one of the sensory, jointed mouth parts of crayfish, insects, etc.

PAN'CREAS (Gk. *pan*, all, + *creas*, flesh): a gland which secretes a liquid containing enzymes used in the intestinal digestion of food.

PAPIL'LA: a small projection, as from the surface of the tongue.

PAP'PUS (Gk. *pappos*, down): the tuft of down on the fruits of certain plants, as thistle, dandelion, for distribution by wind.

PAR'ALLEL VENA'TION: the characteristic venation of monocotyledonous plants in which a number of veins of about the same size run side by side from base to apex of the leaf.

PAR'ASITE (Gk. *para*, beside, + *sitos*, food): a small, dependent organism which gets its food directly from a larger one, the host, without any benefit to the latter.

PASTEURIZA'TION (named from Pasteur, the originator): the process of killing most of the harmful bacteria in milk by heating it for twenty minutes at 60° C. and cooling it quickly.

PEAT: a substance composed of partially carbonized organic matter, chiefly plants, found in bogs, and used for fuel when dry.

PEC'TORAL (Lat. *pectus*, breast) **GIRDLE**: the bones which support the anterior limbs of vertebrates and attach them to the trunk.

PEDUN'CLE (Lat. *pedunculus*, little foot): the axis or stem to which the several flowers of an inflorescence are attached, as in lily of the valley.

PEG OF HYOCOT'YL: the hard portion on the top of the arch of the hypocotyl which protects it from injury and assists it in piercing the soil.

PEL'VIC (Lat. *pelvis*, basin) **GIRDLE**: the bones to which the posterior limbs of vertebrates are attached.

PEL'VIS (Lat. *pelvis*, basin): the broad, curved bones which support the organs of the abdomen.

PEP'SIN (Gk. *pepsis*, cooking): the ferment in the gastric juice which acts on protein.

PEP'TONE: the substance resulting from the digestion of protein by pepsin.

PEREN'NIAL (Lat. *per*, through, + *annus*, year): a plant which lives year after year, as a tree.

PERFECT FLOWER: one which has both stamens and pistil, the essential organs.

PER'IANTH (Gk. *peri*, around, + *anthos*, flower): the sepals and petals of a flower taken together when they are similar in shape and color, as in a lily.

PERICAR'DIUM (Gk. *peri*, around, + *cardia*, heart): the membranous sac surrounding and inclosing the heart.

PERIOS'TEUM (Gk. *peri*, around, + *osteon*, bone): the membrane which covers bones and adheres to them.

PERISTAL'SIS (Gk. *peri*, around, + *stalsis*, constriction): the wavelike motion in the intestine caused by the contraction and relaxation of its muscles.

PERSPIRA'TION (Lat. *per*, through, + *spiro*, breathe): sweat.

PET'AL (Gk. *petalon*, leaf): one of the colored parts which make up the corolla of a flower.

PET'IOLE (Lat. *petiolus*, fruit stalk): the part of a leaf by which it is attached to the stem; the leaf stalk.

PHAG'OCYTES (Gk. *phagein*, to eat, + *cytos*, sac): the white corpuscles of the blood which act as scavengers.

PHAR'YNX (Gk. *pharynx*, gullet): the cavity back of the mouth common to the respiratory and digestive systems.

PHLO'ËM (Gk. *phloios*, inner bark): the outer part of a fibrovascular bundle in a dicotyledonous plant.

PHOS'PHORUS (Gk. *phos*, light, + *phero*, bear): one of the elements; it is found in minute quantities in protein.

PHOTOSYN'THESIS (Gk. *phos*, light, + *synthesis*, putting together): the process of making starch, peculiar to green plants.

PHYSIOLOG'ICAL OXIDA'TION: a slow combustion without flame or smoke, but with the production of heat and the formation of carbon dioxide and water. It takes place constantly in all active organisms.

PHYSIOL'OGY (Gk. *physis*, nature, + *logos*, a talk): the study of the life processes of organisms.

PISTIL (Lat. *pistillum*, from *pinso*, pound): the central part of a flower consisting of a stigma, style, and ovary (which see).

PITH: the soft, spongy tissue in the center of a woody stem; the substance between the vascular bundles in a monocotyledonous stem.

PLACEN'TA (Lat. *placenta*, cake): the tissue to which seeds are attached in the ovary of a plant.

PLAS'MA (Gk. *plasma*, a thing formed): the liquid portion of the blood of vertebrates.

PLECOPTERA (Gk. *plectos*, plaited, + *pteron*, wing): an order of insects having plaited wings, as stone flies.

PLU'MULE (Lat. *plumula*, little feather): the first bud of an embryo plant.

POD: the seed case of certain plants, as pea; a form of dry, dehiscent fruit.

POR'SON (Lat. *potio(n)* from *poto*, drink): any substance which acts in a harmful manner when taken into the system of an organism.

POL'LEN (Lat. *pollen*, fine flour): the fine, powdery substance formed in the stamens of flowers. Each grain contains a sperm nucleus for fertilizing the egg cell in an ovule.

POL'LINA'TION (Lat. *pollen*, fine flour): the act of receiving pollen on the stigma of a pistil.

POME (Lat. *pomum*, fruit): a fruit having thick, fleshy walls which inclose the papery pod containing the seeds, as apple, pear, quince.

POR'TAL (Lat. *porta*, gate) VEIN: the large vein that carries blood to the liver.

POSTE'RIOR (Lat. *posterus*, following) PART: the hinder portion of an organism.

POTAS'SIUM: one of the elements; it is found in minute quantities in protoplasm.

POTEN'TIAL (Lat. *potentia*, power) ENERGY: that which is temporarily inactive, as that in a tight spring.

PRÆCO'CIAL (Lat. *præ*, before, + *coquere*, ripen): birds which are able to run soon after hatching.

PRESERV'ATIVE (Lat. *præ*, before, + *servo*, save): a substance added to food to prevent its "spoiling," as sugar in fruit, salt on meat.

PRESERVE' (Lat. *præ*, before, + *servo*, save): a place in which plants or animals, or both, may not be molested.

PRI'MARY (Lat. *primus*, first) FOODS: all plant foods, and such animal foods as fish and oysters, where the animal gets its nourishment from some other source than primary foods and fodders.

PRI'MARY (Lat. *primus*, first) ROOT: the first and usually the main root of a plant; the tap root.

PRI'MATES (Lat. *primus*, first): a group of animals which stand at the head in intelligence, as monkeys, apes, etc. Man, as an animal, is a primate.

PROBOSCID'IA (Gk. *pro*, before, + *bosko*, feed): a group of animals characterized by a proboscis.

PROBOS'CIS (Gk. *pro*, before, + *bosko*, feed): an elongated appendage for gathering food. In insects, a coiled tube; in elephants, a prehensile nose and upper lip.

PROTEC'TIVE COLORATION: coloration which resembles that of the environment, as that of toad, frog, grasshopper, tree frog.

PROTEC'TIVE RESEM'BLANCE: the resemblance of a harmless organism to a harmful or distasteful one, as viceroy butterfly to monarch.

PRO'TEIN (Gk. *protos*, first): a compound of oxygen, hydrogen, carbon, and nitrogen, with traces of other elements; a component of protoplasm; a nutrient.

PROTHO'RAX (Gk. *pro*, before, + *thorax*, chest): the first of the three regions of an insect's thorax.

PRO'TOPLASM (Gk. *protos*, first, + *plasma*, molded form): the living substance composing the cells of plants and animals.

PROTOZO'A (Gk. *protos*, first, + *zoön*, animal): one-celled animals.

PSEUDOPO'DIUM (Gk. *pseudes*, false, + *pous*, foot): a projection of protoplasm used by Protozoa for locomotion.

PTO'MAINE (Gk. *ptoma*, corpse): a substance produced by the decomposition of animal matter, poisonous if eaten.

PTY'ALIN (Gk. *ptyalon*, spittle): the enzyme in saliva which changes starch to sugar.

PULSE (Lat. *pulsus*, beating): the beating of the arteries near the surface, as at the wrist.

PU'PA (Lat. *pupa*, puppet): the quiescent, inactive stage in the development of an insect between larva and adult.

PU'PIL OF THE EYE: the round opening in the iris which admits light into the eye.

PYLO'RUS (Gk. *pyloros*, gate-keeper): the opening between the stomach and the intestine.

Q

QUAR'ANTINE: the enforced isolation of persons, animals, or plants infected with contagious diseases or of places harboring disease germs.

QUARTER-SAWN TIMBER: that which is sawed lengthwise into quarters to show the medullary (wood) rays obliquely, especially *quartered oak*.

QUEEN BEE: the mother of a community of bees whose only duty is to lay eggs in cells prepared by the workers; a perfect female bee.

R

RACEME' (Lat. *racemus*, cluster): a form of inflorescence in which the flowers are arranged spirally around a central axis, as in lily of the valley.

RA'PHE (Gk. *raphe*, a seam or suture): the band running lengthwise around the outside of a bean seed.

RAPTO'RES (Lat. *rapere*, to ravish): an order of birds having sharp, hooked beaks and strong, sharp talons; birds of prey.

RAY FLOWERS: the outer flowers of certain composite "flowers," for example, common daisy, with white ray flowers, sunflower, with yellow ones.

RECEP'TACLE (Lat. *re*, back, + *capio*, take): the expanded end of a modified branch on which the floral parts are arranged.

RECES'SIVE (Lat. *re*, back, + *cedo*, yield) CHARACTERS: those which do not appear in a hybrid, because of the dominance of other characters.

RECLAMA'TION (Lat. *re*, again, + *clamo*, call): the act of bringing wild or arid land to use in raising crops; supplying water for irrigation.

REC'TUM (Lat. *rectus*, straight): the terminal portion of the alimentary canal.

RED RUST: a parasitic fungus which has two hosts, wheat and barberry, during its life history; called also black rust from its mature stage on wheat.

RE'FLEX (Lat. *re*, back, + *flecto*, bend) ACTION: that which takes place in voluntary muscles without the intervention of the mind. the impulse

going first to the spinal cord and being switched to the motor nerves, causing movement. One of the simplest types of response.

REFORESTA'TION: the act of replanting areas with trees, or setting out trees on new areas.

REGENERA'TION (Lat. *re*, again, + *genero*, beget): the act of restoring a lost part by growing a new one, as the tentacle of a hydra, or the end of an earthworm.

REGULAR FLOWER: one which has all its petals, also its sepals, of the same size and shape, as rose, buttercup. Pansies, violets, and salvia have *irregular* flowers.

REPEL'LENT (Lat. *re*, back, + *pello*, drive): a substance which makes plants distasteful to their insect enemies.

REPRODUC'TION (Lat. *re*, again, + *pro*, before, + *duco*, lead): the act of bringing forth another thing of the same kind; generation.

RESPIRA'TION (Lat. *re*, again, + *spiro*, breathe): the life function which consists of getting and delivering oxygen to protoplasm. See page 17.

RET'INA (Lat. *rete*, net): the inmost layer of the coat of the eyeball which receives the stimuli of light rays and conducts them to the brain through the optic nerve.

RHI'ZOME (Gk. *rhiza*, root): a thickened, underground stem used for food storage, as in Solomon's-seal and Pteris, or for propagation, as in quack grass and Canada thistle.

RODEN'TIA (Lat. *rodo*, gnaw): a group of animals having chisel-edged incisor teeth for gnawing, as squirrel, rat.

ROOT CAP: the loose protective cells covering the end of a rootlet.

ROOT HAIRS: elongated projections of epidermal cells of roots for absorption.

ROOT PRESSURE: the osmotic force which causes sap to rise in stems.

ROSETTE' (Lat. dim. of *rosa*, rose): the spiral arrangement of leaves on a very short axis, as shepherd's-purse or bull thistle in early spring.

RU'MINANT (Lat. *rumen*, throat): an animal which chews its cud, as cow. The food is swallowed with very little chewing while eating. Later it is returned to the mouth partially digested and is thoroughly chewed.

RUST: a form of plant disease caused by certain fungi; especially red rust (black rust) of wheat.

S

SALI'VA (Lat. *saliva*, spittle): the natural moisture in the mouth secreted by the salivary glands.

SAM'ARA (Lat. *samara*, elm seed): an indehiscent winged fruit, as in maple, elm, and ash.

SAN JOSÉ SCALE: an injurious insect which infests fruit trees.

SANC'TUARY (Lat. *sanctio*, make holy): a place of refuge from violence, particularly designated localities where birds or other animals may not be molested.

SANITA'TION (Lat. *sanitas*, from *sanus*, whole): the devising and applying of measures for preserving and promoting health, especially public health.

SAP: the liquids which circulate in plants.

SAP'ROPHYTE (Gk. *sapros*, rotten, + *phyton*, plant): the group of fungi which live on dead organic matter.

SCAP'ULA (Lat. *scapula*, shoulder-blade): one of the shoulder-blades.

SCI'ON: the small branch inserted into the large plant (stock) in grafting.

SCLEROT'IC (Gk. *skleros*, hard) COAT: the tough outer coat of the eyeball.

SCUTE (Lat. *scutum*, scale): one of the large scales on the abdomen of a snake.

SCUT'ELLUM (Lat. dim. of *scutum*, shield): the shield-shaped cotyledon lying under the embryo in corn and other grains.

SECRE'TION (Lat. *se*, aside, + *cerno*, separate): a substance formed in the protoplasm such as an enzyme or a hormone.

SEEDLING: a young plant during the period when it is dependent on food stored in the seed.

SEG'MENT (Lat. *segmentum*, from *seco*, cut): one of the ring-like divisions of the abdomen of insects, and of earthworm.

SELF-POLLINA'TION: the act of getting pollen on the pistil of any flower from its own stamens.

SENSA'TION (Lat. *sensatus*, from *sentio*, feel): the consciousness (awareness) of a stimulus received through a sense organ.

SEN'SORY (Lat. *sentio*, feel) NERVES: those which convey impulses to the brain, producing sensation.

SEX'UAL (Lat. *sexus*, sex) REPRODUC'TION: that in which the new individual arises from the union of an egg and a sperm.

SIEVE CELLS: large cells with perforated ends which are a part of the phloëm of a fibrovascular bundle.

SIMPLE EYE: a single organ of sight found in insects, resembling one of the numerous parts of the compound eyes.

SI'NUS (Lat. *sinus*, bend): a hollow or cavity in a bone; an irregular, widened space in a blood vessel or among the cells of a tissue.

SI'PHON (Gk. *sipho*, siphon): one of the openings in the mantle of a clam through which water flows in or out.

SIPHUNCULA'TA (Gk. dim. of *sipho*, siphon): an order of insects which have sucking mouths, as sucking lice.

SKEL'ETON (Gk. *skeleton*, dried body): the firm part of an animal's body to which the muscles are attached.

SKIN: the outer covering of an animal's body.

SOIL (Lat. *solum*, bottom): the finely divided particles of rock, humus, etc., which make up the outer layers of the earth not covered by water.

SOL'ID (Lat. *solidus*, dense): a form of matter neither gaseous nor liquid, as wood, stone, clay.

SOL'ITARY (Lat. *solitarius*, solitary): single; alone; especially a flower which grows at the end of its own stalk.

SOL'VENT (Lat. *solvo*, set free): a fluid which makes other substances fluid also.

SPAWN: to deposit eggs or roe for reproduction, as fishes.

SPE'CIAL SENSES: seeing, hearing, smelling, tasting, feeling.

SPERM (Gk. *sperma*, from *speiro*, sow): the male element in sexual reproduction.

SPER'MARY (Gk. *sperma*, from *speiro*, sow): the organ which produces sperms; the testis.

SPIC'ULE (Lat. *spiculum*, dim. of *spicum*, point, spike): a small, hard, pointed body found in sponges.

SPI'NAL NERVES: those arising from the spinal cord, a pair between each two vertebræ.

SPIR'ACLE (Lat. *spiraculum*, air-hole): an opening for air in the body of an insect or whale.

SPIRIL'LUM (Gk. *speira*, coil, wreath): a spiral form of bacterium.

SPLEEN (Gk. *splen*, spleen): a ductless organ in the abdominal cavity of vertebrates.

SPORAN'GIUM (Gk. *spora*, a seed, + *angeion*, a receptacle): the case in which spores are produced.

SPORE (Gk. *spora*, a seed); a non-sexual reproductive body common to fungi, mosses, and other plants.

SPRAIN: the injury resulting from a violent twisting or pulling of the ligaments or muscles.

SPUR: a short, stiff, sharp spine, as on a rooster's leg; a projection from a sepal or petal.

SPU'TUM (Lat. *sputus*, from *spuo*, spit): expectorated matter; saliva and material discharged from the lungs.

STA'MEN (Lat. *sto*, stand): the organ in a flower which produces pollen.

STARCH: a substance composed of carbon, hydrogen, and oxygen, hydrogen and oxygen occurring in the same proportion as in water; a carbohydrate.

STEAP'SIN: a digestive ferment found in the pancreatic juice and assisting in the digestion of fats.

STEGOMY'IA: a species of mosquito; see *Aedes*.

STER'ILE (Lat. *sterilis*, barren): free from bacteria of every kind.

STER'NUM (Gk. *sternon*, breast): the breastbone.

STIG'MA (Gk. *stigma* from *stizo*, prick): the part of a pistil which receives the pollen.

STIM'ULANT (Lat. *stimulus*, goad): any agent that excites to organic action.

STIM'ULUS (Lat. *stimulus*, goad): that which causes a reaction in nerve, muscle, or vegetable tissue, as light, sound, electricity, warmth, etc.

STING: an organ of offense or defense in animals, as bees, wasps, etc.; hollow hairs of plants filled with acrid liquid secreted by the plant, as nettle.

STIP'ULE (Lat. *stipula*, stalk): one of the two leaf-like growths at the base of the petioles of certain leaves, as clover, strawberry.

STOCK: the large stem on to which a smaller one (scion) is grafted.

STO'LON (Lat. *stolo*, twig): a thread-like, leafless branch which has a vegetative bud on the end, as in strawberry plants.

STO'MA (Gk. *stoma*, mouth): one of the very small openings in the epidermis of a leaf through which water vapor passes out and air in.

STOM'ACH (Gk. *stomachos*, from *stoma*, mouth): the sac or enlarged portion of the digestive tract in which digestion is carried on.

STRAP-SHAPED FLOWER: one in which the narrow petals are united and turned in the same direction, as in dandelion.

STYLE (Gk. *stylos*, pillar): the slender portion of a pistil connecting the stigma and the ovary.

SUCTO'RIA (Lat. *suctus*, from *sugo*, suck): an order of insects which have sucking mouths, as fleas.

SUF'FOCATE (Lat. *suffocatus*, from *suffoco*, choke): to kill by excluding air from the lungs or by substituting some other gas for air, as smoke.

SUG'AR: a carbohydrate of sweetish taste, soluble in water. (See *starch*.)

SUL'FUR: one of the elements found in protein. It forms an ill-smelling combination with hydrogen in decomposing protein.

SU'TURE (Lat. *sutura*, from *suo*, sew): the joining of two bones by mutually serrated edges, forming an immovable articulation, as in the bones of the skull.

SWARM'ING: the departure from the hive of a queen bee and most of the workers.

SWIMMERETS': small appendages on the abdomen of a crayfish, useful in swimming.

SYMBIO'SIS (Gk. *syn*, together, + *bios*, life): the close relationship of two kinds of organisms which results in mutual benefit.

SYS'TEM (Gk. *syn*, together, + *histemi*, stand): a group of organs which work together to perform a life function, as digestive system, circulatory system.

T

TACH'INA FLY: a useful dipterous insect which lays its eggs on the larvæ of potato beetles.

TAD'POLE: the larval stage of frogs and toads.

TAL'ON (Lat. *talus*, heel): a claw, especially of a bird of prey.

TAR'SUS (Gk. *tarsos*, any flat surface): the ankle; the scaly part of a bird's leg; the terminal segment of an insect's foot.

TEN'DON (Lat. *tendo*, stretch): the connective tissue ending of a muscle which attaches it to other structures.

TEN'DRIL: an organ of certain plants which clasps a support, enabling it to climb.

TEN'TACLE (Lat. *tento*, touch, try): a jointed flexible appendage on the head of insects and other invertebrates, used for touch, grasping, or motion; a feeler.

TER'MINAL (Lat. *terminus*, boundary) BUD: one which appears at the end of a branch or stem.

TER'RAPIN: one of the tortoises or land turtles.

TES'TA (Lat. *testa*, shell): the hard outer covering of a seed.

TES'TIS (Lat. *testis*, a testicle): an organ in a male animal where sperms are produced.

THALES'SA: a useful ichneumon fly which destroys the larvæ of Tremex, a wood borer.

THORAC'IC (Gk. *thorax*, thorax) CAVITY: the second part of an insect's body; in mammals, the cavity above the diaphragm; the chest cavity.

THY'ROID (Gk. *thyreos*, large shield) GLAND: a large ductless gland on the outside of the trachea below the larynx.

THYSANU'RA (Gk. *thysanos*, fringe, + *oura*, tail): an order of insects having bristles on the end of the abdomen, as in fish-moths.

TIB'IA: the shin bone in man; the fourth division of an insect's leg.

TIS'SUE (Lat. *texo*, weave): a collection of similar cells that perform the same function.

TON'SIL (Lat. *tonsilla*, tonsil): one of two ductless glands lying in the throat back of the tongue.

TOX'IN (Lat. *toxicum*, poison): a poisonous substance given off by disease-producing bacteria.

TRA'CHEA (Gk. *tracheia*, windpipe): the air passage leading from the pharynx to the lungs; an air tube in insects.

TRANSPIRA'TION (Lat. *trans*, through, + *spiro*, breathe): the evaporation of water through the stomata of leaves.

TREE SURGERY: the scientific treatment of diseased trees, consisting of pruning, filling cavities, and so on.

TRICHINEL'LA (Gk. *thrix*, hair): a small round worm sometimes found in pork living as a parasite, and the cause of trichinosis in man.

TRICH'OCYSTS (Gk. *thrix*, hair, + *kystis*, bag): minute, dart-like organs of offense and defense found in paramecium.

TRICHOP'TERA (Gk. *trichos*, gen. of *thrix*, hair, + *pteron*, wing): a group of insects having long, hair-like projections from the end of the abdomen.

TROCHAN'TER (Gk. *trochanter*, from *trecho*, run): the second joint of an insect's leg.

TRUNK: the stem of a tree; the main part of the body of a vertebrate to which the appendages are attached.

TRYP'SIN (Gk. *tripsis*, a rubbing): a digestive ferment, found in pancreatic juice and acting on protein substances.

TU'BER (Lat. *tuber*, a swelling): a short, thick underground stem used for storage, as potato.

TUR'GID (Lat. *turgeo*, swell): distended with air or liquid; swollen.

TYMPAN'IC (Gk. *tympanon*, drum) **MEMBRANE**: the thin partition which separates the middle ear from the outer, commonly known as the ear-drum.

U

UNGULA'TA (Lat. *unguis*, nail): a group of mammals characterized by hoofs.

U'REA (Lat. *urina*, urine): the nitrogenous waste of animals which is passed off in the urine.

URE'TER (Gk. *oureter*, from *ouron*, urine): a tube, one of two, leading from the kidneys to the bladder and carrying off the waste from the kidneys.

URINOGEN'ITALS (Lat. *urina*, urine, + *genitalis*, from *gigno*, beget): the organs common to the urinary and the reproductive systems, or the combination of these systems.

U'ROPOD (Gk. *oura*, tail, + *pod*, from *pous*, foot): the modified swimmeret on either side of the last segment of a crayfish. These, together with the telson (the modified last segment), make up an appendage useful in swimming backwards.

V

VACCINA'TION (Lat. *vacca*, cow): inoculation with the virus of cowpox as a preventive of smallpox. The term is loosely used to denote inoculation for other diseases.

VACCINE' (Lat. *vacca*, a cow): the virus of cowpox prepared for or introduced by vaccination.

VAC'UOLE (Lat. *vacuus*, empty): a space in the protoplasm of a cell usually filled with a clear liquid secreted by the cell, or by food in the process of digestion.

VALVE (Lat. *valva*, leaf of a door): one or more folds in the lining tissue of a blood vessel or other organ to prevent or check the flow of a liquid in the opposite direction.

VARIA'TION (Lat. *varius*, various): deviation from the type in structure or function.

VAS'ULAR (same as fibrovascular) **BUNDLES** (Lat. *vasculum*, a little vessel): elongated cells which communicate with one another, forming tube-like vessels for the transportation of liquids in plants.

VEIN (Lat. *vena*, blood vessel): one of the vessels which conduct blood towards the heart; one of the ribs of an insect's wing; one of the larger supporting and conducting vessels in a leaf.

VELA'MEN (Lat. *velare*, to veil): the outside layer of an aerial root of certain orchids. It is adapted to gather water.

VENTILA'TION: the control of the supply, circulation, temperature, and humidity of the air in a room.

VEN'TRAL (Lat. *venter*, belly): pertaining to or situated on the abdominal side of the body.

VEN'TRICLE (Lat. *ventriculus*, a little belly): any cavity of a hollow organ, especially one of the lower chambers of the heart.

VER'MIFORM (Lat. *vermis*, worm, + *forma*, form) **APPEN'DIX** (Lat. *ad*, to, + *pendo*, hang): a slender tubular pouch of the large intestine at its juncture with the small intestine.

VER'TEBRATES (Lat. *verto*, turn): the group of animals which have back-bones.

VIABIL'ITY (Lat. *vivo*, live): having life or the ability to live, as a seed.

VIL'LI (Lat. *villus*, a hair): the minute projections which cover the lining of the small intestine; an organ of absorption.

VI'RUS (Lat. *virus*, poison): the element or principle that is the agent or medium for communicating infection.

VIS'CERA (Lat. *viscus*, an organ of a cavity of the body): the organs of the abdominal cavity.

VI'TAMIN (Lat. *vita*, life): certain substances in foods which are necessary for the proper functioning of the vital processes.

VIT'REOUS (Lat. *vitrum*, glass): the liquid which fills the posterior chamber of the eyeball.

VOLUNTARY (Lat. *voluntas*, will) **MUSCLES**: those under the control of the will, as the hand.

VOLVOX: a colonial organism in which certain cells are set apart for reproduction.

W

WARM-BLOODED: having a constant temperature, as man.

WARN'ING COLORA'TION: marks or colors which make an insect or other animal conspicuous to its enemies.

WEED: a plant that grows where it is not wanted.

WIG'GLER: the larva of mosquitoes.

WORKERS: underdeveloped females in a community of bees which perform all the work of the hive except reproduction.

WORM: a group of animals having flat or cylindrical bodies which in some cases are composed of segments.

X

XY'LEM (Gk. *xylon*, wood): the thick-walled cells in a fibrovascular bundle.

Y

YEAST: a unicellular fungus which causes fermentation.

YOLK: the yellow portion of an egg; the food material used by the embryo.

Z

ZY'MASE (Gk. *zyme*, a ferment): a ferment found in yeast.

INDEX

References are to pages.

- Abdomen**, of crayfish, 105, 106, 110
 of grasshopper, 57, 58, 59
 of man, 426
- Abdominal cavity**, 426
- Abnormal growth of tissue cause of disease**, 510
- Absorption**, a life process, 17
 of food in man, 468
 of food nourishment, 470
 of nutrition, 17
- Accessory buds**, 240
- Accessory parts of flower**, 258, 260
- Acid medium in stomach**, 467
- Acquired immunity**, 378, 519
- Active immunity**, 519
- Adam's apple**, 451
- Adaptation**, discussed, 18-21
 illustrated in appendages of crayfish, 106, 107
- Adaptations**, examples of, 18
 for attracting insects, 260
 for pollination, 263, 267
 of animals, 20
 of birds, 162-165
 of composites, 270
 of dandelions, 268
 of excretory organs, 468
 of fishes for swimming, 127
 of fleshy fruits, 275
 of fruits and seeds for dispersal, 274
 of fruits to distribution by water, 276
 of honeybee, 99-100
 of individuals, 18-21
 of intestine for absorption, 468
 of leaves of grass, 219
 of mammals, 199-202
 of man, 409
 of monocotyledonous stems, 242
 of nasturtium, 267
 of reptiles, 158-159
 of rose stem, 242
 of seed, 283
 of skeleton, 199
 of stems, 241
 of wood, 247
- Adrenal glands**, 497
- Adrenalin**, 497, 499
- Adulteration of foods**, 479
- Adventitious roots**, 252
- Aedes**, harmful mosquito, 83, 517
- Aërial roots**, shoots of underground stems, 244, 251
- Aërial stems**, 236, 237
- Aërobic bacteria**, 342
- Age of Insects**, 53
- Age of trees**, how told, 298
- Agents**, for distributing pollen, 265
 for distributing seeds, 274
- Aggressive coloration**, 87
- Aigrettes**, importation of forbidden, 170
- Air**, home of bacteria, 339
- Air cells of lung**, 451
- Air sac**, 451
- Air spaces in stems**, an adaptation, 242
- Air tubes of birds**, 164
- Airplanes used in locating forest fires**, 293
- Akene**, 271, 275
- Albumen**, example of protein, 467
- Alcohol**, a narcotic, 533
 a poison, 532, 533
 ambition destroyed by, 534
 and disease, 524, 535
 and efficiency, 536
 and "patent" medicines, 537
 as a food, 535
 avoidance of, in consumption, 513
 cause of disease, 524, 535
 effect of, on digestion, 535
 effect of, on nervous system, 535
 formed by yeast plant, 327, 328
 in bread driven off by heat, 328
- Alcoholism a disease**, 524, 535
- Alfalfa**, root system of, 253

- Algæ**, 216, 316-320
 chlorophyll, 317
 classification of, 317
 diatoms, 320
 digestion of, 317
 filamentous, 317
 habitat, 316
- Alimentary canal**, of frog, 143
 of man, 463
- Alkaline medium**, in intestine, 468
 in mouth, 467
- Alligators**, distribution of, 158
 example of reptiles, 155
- Alternate leaves of elm**, 219
- Alternation of generations**, of ferns, 310, 313
 of marchantia, 316
 of mosses, 315
- Altricial birds**, 165
- Amanita**, 327
- Amateur entomologists**, 66
- Ameba**, 330-333
- American grape**, immunity of, 378
- American Ornithologists' Union**, 171
- Ammonia in test for protein**, 287
- Amphibians**, described, 140
 economic importance of, 153
 examples of, 140
 hibernation of, 151
 list of, 140
 summary of, 153
- Anaërobic bacteria**, 342
- Anæsthetic**, defined, 532
 dissolves lipid, 535
- Angular leaves**, 219
- Animals and plants of future**, 373
 by breeding, 385
- Animal oils**, 209
- Animal parasites**, habits of, 119
- Animal preserves**, 171, 203-204
- Animal starch**, in liver, 470
- Animals**, agents in distribution of seeds, 275
 dead, decomposed by bacteria, 339
 eaten by skunks, list of, 190
 without a backbone, 104, 113
- Annual growth**, 242
- Annual rings**, age of tree told by, 298
 in stem of pine, 298
- Annual roots**, 253
- Annual stems**, 243
- Anopheles mosquito**, 83, 516
- Ant bear**, example of toothless mammal, 189
- Anteater**, example of toothless mammal, 189
- Antennæ**, of crayfish, 107
 of grasshopper, organs of smell, 57
- Anterior metatarsal arch**, 437
- Anther**, adaptation for pollination, 267
 described, 258, 259
- Antheridia**, of marchantia, 316
 of mosses, 315
 of Pteris, 312
- Antiseptic**, action of creosote on railroad ties, 306
- Antiseptic surgery**, 528
- Antitoxin**, discussed, 347, 519, 520, 521
 use in diphtheria, 521
- Ants**, eaten by flicker, 177
 example of Hymenoptera, 67
 life history of, 101
 social life of, 100
- Anus**, in the digestive system of man, 465
- Aorta**, largest artery in man, 447
- Ape**, a primate, 189, 197
- Aphid**, example of Homoptera, 67
- Appendages**, of crayfish, 106
 of grasshopper, 57, 58
 of vertebrates, 125
- Appendicitis**, 464
- Appendix, vermiform**, 464
- Apple juice**, cause of fermentation in, 329
- Apple tree**, a representative flowering plant, 215
 life of, 1
- Apple wood**, use of, 307
- Aquatic Carnivora**, 189
- Aquatic stems**, 251
- Aqueous humor**, 489
- Arachnids**, a group of crustaceans, 115
- Arbutus**, destruction of, 272
- Arch**, of foot, 439
 of hypocotyl of bean, 284
- Archegonia**, of marchantia, 316
 of Pteris, 312, 313
- Arctic tern**, migration of, 181
- Arms**, example of organ, 48
- Army worm**, harmful insect, 167
 list of bird enemies, 167
- Arsenic**, a poison, 510
- Arteries**, function of, in man, 446
 of crayfish, 110
 of fishes, 129
- Arthropoda**, word explained, 104

- Articulation of bones**, 431
Artificial pollination, 266
Artificial respiration (breathing), 453
Aseptic, defined, 343
Aseptic surgery, 528
Asexual reproduction, 324, 325
Ash, result of chemical change, 30
Ash tree, for shade, 303
Ash wood, use of, 304, 307
Asparagus, a leafless plant, 233, 244
 stem of, used for food, 245
Asparagus beetles, 74
Assimilation, a life process, 17, 226
 in man, 448
 of nutrition, 17
 on plants, 232
Astigmatism, 493
Atmosphere, composition of, 26
Auditory organ of grasshopper, 58
Audubon Society, 171
Auricles of heart, 446
Axillary buds, 240
Ayrshires, breed of cattle, 195
- Bach family**, 393
Bacillus, a form of bacteria, 338
Bacillus tuberculosis, cause of consumption, 512-515
Backbone, characteristic of vertebrates, 124
Bacteria, aërobic, 342
 anaërobic, 342
 and human welfare, 340, 550
 cause of certain plant diseases, 340
 cause of decay, 8
 cause of sour milk, 344
 conditions necessary for growth, 339
 control of, 345
 dairy, 344
 decomposition of materials by, 339
 discussed, 340
 effect of cold on, 344, 345
 effect of enzymes and, 468
 food of, 339
 forms of, 338
 harm to teeth from, 462
 harmful, 340
 helpful, 340, 341
 important plants, 338
 in relation to milk, 344
 in roots of leguminous plants, 340
 inoculation of soil with, 340
 life processes of, 339
 multiplication of, 339
 of soil, 340
 other names for, 338
 presence, in polluted water, 525
 prevention of growth of, 306
 reproduction of, 339
 shape and size, 338
 source of disease, 340
 summary of, 347
 unfavorable conditions withstood by, 339
 where found, 339
 work of, in digestion, 468
Bacterial poison, toxin, 347
Bailer in gill chambers of crayfish, 109
Balanced diet, 473
Balancing, use of fins for, 126, 127
Balancing organ, of crayfish, 108
Baldwin apple, 8, 9
Ball and socket joint, 431
Balloon spider, 115
Balsa wood, 304
Balsams, conifers, 300
 roots on, 244
 same as firs, 297
 soft wood of, 300
Baltimore oriole, discussed, 174
 migration of, 181
Bananas, seedless fruits, 278
 value of, as food, 278
Barberry, thorns of, 223
Bark of hemlock, use of, 301
Barley, a cereal, 277
 improvement of, 387
Barn swallow, discussed, 177
Barnacles, crustaceans, 112
Bass, a bony fish, 125
 care of eggs by, 131
 insects its food, 128
Basswood, characteristics of, 307
 source of excelsior, 307
 uses of, 307
Bat, discussed, 197, 205
 enemy of mosquito, 83
 flying mammal, 189
Bathing, 423
Beaks of birds, for defense, 163
 variations in, 163
Bean, embryo, growth of, 284
 example of dicotyledons, 286
 foodstuffs in, 288
 from ovule to seed, 282
 fruit of, how distributed, 276
 germination of, 284
 roots of, 253

Bean — Continued

- seed, laboratory study of, 286
- seedling, parts of, 285
- source of protein, 288
- Bean (pulse) family**, members of, 288
- Bear**, example of carnivorous animal, 189, 200
- Beaver**, 189, 191, 207
- Bee farms**, escape of bees from, 94, 98
- Beef**, type of cattle, 195
- Bees**, 5, 94-100
- Beet**, biennial plant, 253
 - source of sugar, 254
 - storage of food in, 254
- Beetle**, May, a harmful insect, 74
 - potato, a harmful insect, 74
- Beetles**, 73
- Beggar's-tick**, distributed by animals, 275
- Behavior of ants**, 100
- Beneficial birds named**, 167
- Beneficial insects in Diptera**, 82
- Beriberi**, cause of, 476
- Berry**, 271
- Biceps muscle**, 435
- Biennial roots**, 253
- Bile**, a digestive juice, 468
- Biological diseases**, kinds, 511
- Biological hobbies**, 547-561
 - discoveries, 558
 - photography, 556
- Biological terms defined**, 15-37
- Biology**, and vocations, 545
 - defined, 1, 11
 - of human body, 400
 - of plants, 215
- Bird baths**, 184
- Bird lice**, 81
- Bird refuges**, 170, 171
- Birds**, adaptation of, 162
 - aid in fighting insects, 304
 - beneficial wild, list of, 167
 - characteristics of, 164
 - classified, 161
 - common, 172
 - destroyers of grasshoppers, 64
 - economic importance of, 167
 - enemies of butterflies and moths, 93
 - enemies of frogs, 151
 - famous students of, 161
 - harmful wild, list of, 168
 - natural enemies of insects, 70
 - number of, 172
 - protection of, 169-171
 - summary of, 186

- Birds' feet**, different kinds of, 162, 163
- Bird's-eye maple**, 306
- Bitter**, a fundamental taste, 461
- Bittern**, beak of, 163
- Black poll warbler**, migration of, 181
- Black raspberries**, protected by thorns, 241
- Black swallow-tail butterfly**, 90
- Black walnut**, used for furniture, 307
- Blackbirds**, food of, 74, 94, 167
- Bladder in man**, 455
- Blade of grass**, main part, 218, 221
- Blanching of celery**, 228
- Blood**, 442-445
 - change of color in, 447
 - corpuscles, 442, 443
 - heat, 444
 - of man, 442
 - plasma, 443
 - pressure in man, 445
 - supply of muscle, 433
 - vessels, function of, 446
- Blossom**, first step in production of fruit, 4
 - parts of, 4, 5
- Blubber of whale**, 202
- Blue-green algæ**, 317, 318
- Blue jay**, beneficial, 167
 - feeds on larvæ of Lepidoptera, 94
- Bluebird**, a beneficial bird, 167
 - destroyer of larvæ of butterflies and moths, 94
 - discussed, 172
 - food of, 172
- Boa constrictor**, 157
- Boards of Health**, 518, 523
- Bobolink**, migratory habits of, 181
 - nest of, 162
 - summer resident, 161
- Body**, parts of, in earthworm, 122
 - in fish, 125
- Body cavities of mammals**, 188
- Body louse**, 82
- Body regions**, of grasshopper, 57, 58
 - of man, 426
- Body regulators**, 29, 466
- Body temperature**, of birds, 164
 - of mammals, 188
 - of man, 444
- Bok**, Edward, 171
- Boll weevil**, injurious insect, 74
- Bone**, and cartilage, 429

- cells of, 430
- fat, uses of, 209
- structure of, 429
- Bones**, arrangement of, in fore limbs, 199
- broken, 431
- of fingers of bat, 197, 199
- of skull of man, 431
- Boneset**, medicinal plant, 232, 246
- Bony fishes**, examples of, 125
- Borers**, eaten by woodpeckers, 74
- insect enemies of tree, 3
- Botany**, relation to plant biology, 215
- Boxwood**, use of, 304, 307
- Bracket fungi**, effect on trees, 294, 326, 328
- Brain**, of crayfish, 110
- of mammals, 188
- of man, 484
- of primates, 197
- parts of, 145
- source of nerves, 145
- Brain case of frog**, 144-146
- Branches of evergreens**, 298, 299
- Brazil nut**, a seed, 278
- Bread**, crumbs for feeding station, 183, 184
- importance of, as food, 474
- mold, 325
- use of yeast in making, 328
- Bread-making**, scientific basis of, 326, 328
- Breastbone of birds**, 164
- Breathing**, in grasshopper, 57, 58
- in man, 451-454
- not respiration, 17
- Breathing center in developing embryo**, 485
- Breeding**, improvement of plants and animals by, 385
- Breeding habits**, of fish, studied, 136
- of fresh-water clams, 118
- Breeding period of fishes** basis of protective laws, 136
- Briars**, an adaptation, 242
- Broad-leafed trees**, examples of, 297
- Broken bones**, 431
- Bronchus**, 451
- Brook trout**, caught for sport, 135
- raised in hatcheries, 136
- Brown algæ**, 317, 319
- Brown creeper**, at suet station, 184
- food of, 94
- Brown rat**, a pest, 192
- Brown-tail moths**, 90
- Bubonic plague**, a bacterial disease, 511
- carried by rodents, 82, 193
- Budding**, man's use of, 8
- Buds**, a characteristic of stems, 240
- in reproduction of yeast plant, 328
- Buffalo's milk**, 470
- Bugs**, members of Hemiptera, 66
- Bulb**, 236, 237
- Bullfrog**, time required for development, 149
- Bullhead**, insect-eating fish, 128, 130
- Bumblebee**, carrier of pollen, 94
- Buoyancy of fruits distributed by water**, 276
- Burdock**, distribution of seed by animals, 275
- Bureau of Animal Industry**, 211
- Bureau of Biological Survey**, 204
- Bureau of Entomology**, 65
- Bureau of Fisheries**, 138
- Butcher bird (shrike)**, 63, 73
- Butter**, 467
- example of animal fat, 209
- flavor of, due to bacteria, 340
- value of, as food, 467, 476
- Butterflies**, classified, 67
- complete metamorphosis of, 90-92
- Butterfly**, swallow-tail, 90
- Buzzards**, food of, 168
- By-product of photosynthesis**, 227
- By-products of conifers**, 301
- Cabbages**, vitamins in, 476
- Cactus**, lacks leaves, 233
- length of roots of, 253
- reduction of transpiration in, 230
- Calamites**, 366, 368
- Calcium**, found in carrots, 29
- use of, in the body, 29, 474
- Calcium oxalate**, in sour grass, 231
- California**, greatest variety of birds in, 172
- Calorie**, 473, 474
- Calyx**, described, 258
- Cambium**, 238
- Cambrian period**, 366, 367
- Camel**, economic importance of, 204
- milk of, 471
- Camomile**, flowers of, used in medicine, 277
- Canada thistle**, 244
- Canaries**, bred in Harz mountains, 169
- domestic bird, 168

- Canary seed in attracting birds, 183
 Cancer, 510
 Canine teeth, 189, 461
 in Carnivora, 189
 lacking in rodents, 191
 Canker worm, 90
 Canning, 345
 Capillaries, 446
 Capillary circulation, 469
 Capsule, 271
 Carbohydrates, a class of food, 27, 473
 constituents of, 473
 digestion of, 467
 manufacture of, 39, 227
 stored by bean, 486
 use of, 466
 Carbon, 26
 Carbon cycle, 342
 Carbon dioxide, a gas, 30
 a waste product of respiration, 30, 453
 formed by burning, 7
 formed by yeast plant, 328
 used by plants, 39
 Carbonic acid gas, 30, 327
 Cardiac valve of stomach, 464
 Carnivora, a group of mammals, 189
 Carrier of disease, 522
 Carrion beetle, beneficial insect, 74
 Carrot, example of biennial, 253
 leaves of, 219
 source of calcium, 29
 storage of food in, 255
 Cartilage, 429
 rings in air passages, 451
 where found on ribs, 428
 Casein, a form of protein, 28
 articles made from, 209
 Castor oil, 289
 Cat, a carnivorous animal, 189, 190
 Catalpa, an ornamental tree, 303
 Catbird, 173
 Caterpillars, destructive insects, 77
 home study of, 81
 larvæ of butterflies, 81
 stage in metamorphosis, 91
 Catnip, a medicine, 232, 246
 Catnip oil, use of, in catching big "cats," 206
 Cattle, hoofed animals, 189
 value of, to man, 195
 Caudal or tail region of fish, 126
 Cauliflower, use of, 277
 Caustic soda in Fehling's solution, 43
 Cavities in the body of man, 426
 Cavity of a tooth, 462
 Cedar, a conifer, 300
 lasting qualities of, 305
 leaves of, 300
 of Lebanon, age of, 243
 uses of, 307
 Celery, blanching of, 228
 Celery "worm," larva of swallow butterfly, 81
 Cell, described, 46
 division, methods of, 47
 name given by Hooke, 46
 parts of, 46
 size of, 48
 unit of structure, 46, 311, 312
 wall, 46, 330
 Cellulose, use of in food, 474
 Cenozoic period, 366, 367
 Centipedes, 116
 Central axis of pine cone, 300
 Central cylinder of root, 250
 Central nervous system, of frog, 145
 of man, 484
 Cephalothorax of crayfish, 105
 Cereal foods, 277, 278, 279
 Cerebellum, of amphibians, 145
 of child, 486
 of man, 484
 Cerebral hemisphere of frog, 145
 Cerebrum of man, 484
 Cetacea, 189
 Chameleon, a lizard, 156-157
 Chara, food of crayfish, 108
 Character, Mendelian, 382
 Charring of timber delays decay, 306
 Cheese, example of protein, 286
 flavor of, 340
 Cheese skipper, 82
 Chela of crayfish, 106
 Chemical change, defined, 25
 in ripe leaves, 224
 Chemical compounds, 23
 Chemicals, used to preserve wood, 306
 Cherry, example of drupe, 274
 wood used for furniture, 307
 Chest cavity of man, 426, 427
 Chicadee, discussed, 174
 destroyer of eggs and larvæ, 94
 Chickens, raised for food, 168
 Chiggers, 116
 Chimney swifts, feet of, 163
 Chipmunk, 191
 Chipping sparrow eats insects, 94

- Chiroptera**, a group of animals, 189
discussed, 197
- Chitin**, outer covering of insects, 56
- Chlorine**, an element in living things, 27
- Chloroform**, action on lipoid, 535
example of anaesthetic, 535
- Chlorophyll**, in mosses, 314
removal from autumn leaves, 224
use in photosynthesis, 39, 228
- Chlorophyll bodies**, 224, 225
- Chloroplasts**, seat of chlorophyll, 39
- Choroid coat of eye**, 489
- Christmas greens**, 309, 313
- Chromosomes**, 380
- Cicada**, discussed, 72-73
example of Homoptera, 67
- Cigarette smoking**, effect of, on eyes, 541
- Cilia**, in air passage, 452
of paramecium, 333, 334
- Circulation**, a life process, 17, 226, 231, 356, 357
in crayfish, 110, 356, 357
in fish, 129, 356, 357
in man, 446
in plants, 226, 231, 356, 357
of nutrition, 17
review of, 356, 357
- Civet**, a carnivorous animal, 189
- Cladophyll**, 236, 237
- Clam**, example of mollusk, 118
fresh-water, life history of, 118
- Clasping base of grass leaves**, 222
- Classification**, of birds, 161
of diseases, 510
of insects, 66, 67
of seeds, 286
- Claws**, of birds, use of, 163
- Cleistogamous flowers**, 265, 266
- Clematis**, use of petioles in, 223
- Climbing plants**, 223
- Climbing roots**, 251
- Climbing stems compared with trees**, 236, 237, 243
- Cloaca of frog**, 143
- Closed season**, for birds, 169
for fishes, 135
- Clothes moths**, 77, 90
- Clothing**, source of, 245, 289
- Clotting of blood**, 444
- Clover**, affected by darkness, 224
- Club mosses**, 309, 313, 365, 369
- Cluster of bees in swarming**, 98
- Coal**, formation of, 310, 369
potential energy in, 35
- Cobra**, most deadly snake, 157
- Cocaine**, 532
- Coccus**, a form of bacteria, 338
- Cocklebur**, adaptations of, 276
- Cockroaches**, 63
- Coconut**, a fruit distributed by water, 20, 276
- Cocoon**, of codling moth, 9, 76
of insects eaten by birds, 94
- Cod**, a useful bony fish, 125
- Codling moth**, a harmful Lepidoptera, 6, 76-77
- Cold**, a common disease, 517
- Cold climate favorable to evergreens**, 301
- Cold storage**, prevents insects from developing, 11, 69
purpose of, 344
- Cold-blooded animals**, 130, 158
- Coleoptera**, 67, 73-74
- Collar of grass leaf**, 222
- Colonial life of beavers**, 192
- Color**, in birds, 164, 165
of arctic animals an adaptation, 200
of reptiles an adaptation, 159
use of, in flowers, 4
- Coloration and mimicry among insects**, 86
- Communicable diseases**, 511
- Community life among insects illustrated by bees**, 94
- Compass plant**, 224
- Complete flower**, definition of, 260
- Complete metamorphosis of insects**, 90, 91
- Complexion**, 422, 423
- Composite flowers**, 261
- Composites**, adaptations of, 270
examples of, 261
- Compound eyes**, of crayfish, 108
of grasshopper, 57
- Compound leaves**, 222
- Compounds**, 23
- Cone-bearing trees**, 298
- Cones (fruit) of pines**, 298, 300
- Conifers**, general characteristics, 298
related forms of, 300
- Conservation**, of energy, 35
of forests, 291
of health, 528
of land, 296
of matter, 36
of useful mammals, 206, 207
of wild flowers, 270

- Conservation Commission**, source of information, 138
Conservation Law of New York State, 170
Consumption, treatment of, 513
Contact poisons for insects, 70
Contractile vacuole, of ameba, 331, 332
 of paramecium, 334
Convolvulus, 259
Cooper's hawk, harmful, 168
Copper sulfate in Fehling's solution, 43
Copperhead snake, 157
Cord of muscles (tendon), 434
Core, in pome fruits, 274
Corium, 417, 418, 419
Corn, embryo leaves of, 286
 example of monocotyledon, 235, 286
 flowers, 267
 food for domestic animals, 277
 laboratory study of, 287
 leaves, behavior of, in drought, 229
 "seed," comparison with bean, 286
 seedling, 285, 287
 stalk, monocotyledonous stem, 239
Corn borer, destructive insect, 79, 90
Cornea of eye, 488, 489
Corolla, described, 258
Corpuscles, red and white, 442, 443
Cortex of root, 250, 252
Cortland apple, 561
Corymb, 259
Cosmetic preparations, 423
Cotton, source of clothing, 289
Cottonboll weevil, 66
Cottonboll worms, 90
Cottontail rabbit, 193
Cottony cushion scale, 72
Cotyledon, of bean, 283, 286
 of corn, 286
 part of seed, 283
Cow, 195
Cowpox, 520
Coyote, a carnivorous animal, 189
Crabs, economic importance of, 111
 example of Crustacea, 104
Cranium, of frog, 145
 of man, 425, 427
Crayfish, 104-112
Creosote, preservative of woods, 306
Cricket, harmful insect, 63
 member of Orthoptera, 62, 66
Crinoids, 117
Crocodiles, 158
Cro-Magnons, extinct race of men, 405
Cross-pollination, 5, 9, 266, 267
Crow, destroyer of larvæ, 74, 94
 discussed, 173
 food of, 63, 74, 94, 167, 168
Crown, part of flower, 260
 part of tooth, 460
Crustacea, 104
 contrasted with mollusks, 118
 contrasted with spiders, 115
 economic importance of, 111, 112
 food of fishes, 112, 128
 harmful to man, 111
Cryptobranchus, a salamander, 140
Cuckoos, food of, 74, 94, 167
Cud-chewing, 194
Culex mosquito, 83
Culture, for Protozoa, 330
 of bacteria, 346
Cures, of quacks, 524, 539
Curly maple, 306
Cuticle of paramecium, 333
Cutin of leaf, 224
Cut-worm, harmful insect, 90
Cyclops, a small crustacean, 112
Cycle, carbon, 342
 nitrogen, 343
 oxygen, 342
Cyme, 259
Cypress trees, conifers, 300
 knees of, 252
 lasting qualities of, 305
 leaves shed, 301
 use of, 307
Cypress wood, 307
Cytoplasm, of cells, 46
 of nerve cells, 483
 of protoplasm, 331
Daddy-long-legs, an arachnid, 116
Dairy cow, 195
Daisy, a composite flower, 261
 disc of, 259
 ray of, 259
Dam of beavers, purpose of, 192
Dandelion, 244
 a composite, 261, 270
 a successful plant, 270
 adaptations in, 266, 268
 food for man, 275
 perennial root, 253
 used in medicine, 275
Darkness, effect of, on clover and oxalis, 224

- Darwin, family, 393
 scientist, 122
 Dead matter simplified by bacteria, 339
 Death caused by insects, 68
 Decay, caused by bacteria and fungi, 7, 306, 339
 Decomposition caused by bacteria, 339
 Deer, even-toed, 194
 ungulates, 189
 Deer mouse, 191
 Defense, adaptations of beaks for, 163
 organs of, in paramecium, 333
 Definite annual growth, 242
 Definitions of common biological terms, 15-37
 Dehiscent fruit, 271
 Deliquescent stem, 236, 237
 Demonstration, of cell, 47
 of digestion, 43
 of oxidation, 42
 of photosynthesis, 40
 Denitrifying bacteria, 343
 Dentine of tooth, 462
 Department of Agriculture of United States, investigations concerning cottony cushion scale, 71
 Development, of life, 364
 of nervous system, 485
 of new animals and plants, 373
 of tadpole, 149
 Devil's-paintbrush, a weed, 245
 Diaphragm, characteristic of mammals, 188
 of man, 427
 passage of esophagus through, 462
 Diastase, an enzyme, 43
 similar to ptyalin, 231
 Diatoms, 320
 Dicotyledons, group of plants, 238
 represented by bean, squash, etc., 235
 kind of venation in, 219
 Diet, 466
 Digestion, a life process, 17, 226, 324, 331
 completed in intestine, 468
 defined, 42
 described, 464
 effect of alcohol on, 535
 in frog, 143
 in paramecium, 334
 in plants, 231
 laboratory study of, 43
 of food in leaf, 231, 232
 of food in seed, 287
 work of, 459
 Digestive fluids, of man, 467-468
 Digestive glands, 459
 Digestive organs, of crayfish, 109
 of frog, 143
 of man, 459
 Digestive system, of animals, student report on, 465
 of crayfish, 109
 Diphtheria, antitoxin for, 521
 carriers of, 522
 Diptera, order of insects, 67, 82-84
 Disc flowers of composites, 263
 Disease, cause of, 510
 results of, 509, 510
 student report on, 522
 Disease-resisting varieties of grain, 379
 Diseases, carried by lice, 82
 caused by abnormal growth of tissues, 510
 caused by bacteria, 340
 caused by fungi, 326
 caused by plants or animals, 510
 caused by poisons, 510
 of plants, 510
 Dispersal of seeds, 271, 274
 Divided leaves, 219
 Division of labor, in digestive system of man, 459
 Dodder, leafless plant, 233
 Dog, 189, 190
 Dogwood, picking of, 272
 Domestic birds, 168
 Domestic fowl, wings of, 163
 Dominant characters, 382
 Donkey, 194
 Dough in bread-making, 328
 Doves, domestic birds, 168
 Downy woodpecker, a permanent resident, 161
 discussed, 176
 Dragon flies, enemies of mosquito, 83
 member of Odonata, 67
 Drones (bees), 94, 96
 Drowning, a form of suffocation, 453
 Drug habits, 532
 Drugs under Food and Drugs Act, 480
 Drupe, examples of, 271, 274
 Dry season, effect of, on annual ring, 243
 Drying, method of preserving food, 345
 of timber, 305
 protection of bacteria from, 339

- Ducks**, closed season for migratory, 169
domestic birds, 168
feet of, 163
- Ductless glands**, 144, 496
- Eagle**, 162, 163
- Ear**, balancing organ, 108, 494
of crayfish, 108
of fish, 125, 130
of grasshopper, 58
of man discussed, 493
organ of sound, 493
pistillate flower of corn, 267
trouble, 494
wax in, 494
- Earth**, birth of, 363
composition of, 362-363
- Earthworm**, 121, 551
economic importance of, 123
life processes of, 122
- Echinoderms**, 117
- Economic importance**, of amphibians, 153
of birds, 167, 171
of conifers, 301
of crustaceans, 111
of earthworms, 123
of fish, 135
of flowers and fruits, 277
of forest products, 306
of grasshopper, 62
of health, 509
of insects, 67
of leaves, 232
of mammals, 204
of roots, 254
of seeds and seed products, 288
of stems, 245
- Economy in the purchase of foods**, 477
- Ectoderm**, of hydra, 322
- Ectoplasm of ameba**, 331
- Edentata**, a group of mammals, 189
- Edible fats**, 27
- Edible pulp of fruit**, factor in distribution, 275
- Edwards family**, 393
- Eels**, life history of, 132
- Egg**, white of, example of protein, 466
- Egg cell**, of frogs, 148
of Volvox, 336
- Egg nucleus found in ovule**, 265
- Eggs**, of frogs, 148
of grasshopper, 60
of insects eaten by birds, 94
- Egret plumes**, importation of, prohibited, 170
- Elder**, use of flowers of, 277
- Elements and compounds**, 23
- Elephant**, 20, 200, 420
- Elk**, protected in New York State, 207
- Elm tree**, 219, 303
- Embryo**, 282
corn, position of, 285
growth of, in ovule, 282
heart of human, 485
parts of, 282
- Encystment of ameba**, 332
- Endocrine**, 496
system, 498
- Endoderm**, of hydra, 322
- Endoplasm of ameba**, 331
- Endoskeleton of fish and frog**, 104
- Endosperm**, 285
- Enemies**, of butterflies and moths, 93
of forests, 293
of frog, 151
of insects, 75
of mosquitoes, 83
- Energy**, conservation of, 35
discussed, 32
forms of, 33
furnished by carbohydrates, 467
kinds of, 32
used by birds, 164
uses of, in body, 467
- English sparrow**, destroys weevils, 74
discussed, 174
eats larvæ of Lepidoptera, 94
permanent resident, 161
- English walnut**, protein in, 466
- Entomologists**, work of, 65
- Environment**, and insects, 69
and the individual, 412
defined, 50
most favorable to man, 412
- Enzymes**, discussed, 42, 467
in pancreatic juice, 468
of yeast plant, 327
secreted by bacteria, 340
- Epidemics**, 522
prevention of, 523
- Epidermis**, of desert plants, 226
of leaf, 224
of root, 250
of rootlets, 250
outer layer of skin, 417
- Epiglottis**, 450
- Equisetum**, 309, 313

- Erosion, 296, 297
- Esophagus, of crayfish, 109
 - of fish, 128
 - of frog, 143
 - of man, 459, 464
- Essential oils, 273
- Essential parts of flower, 258, 260
- Ether, an anæsthetic, 532
- Eugenics, 390-392
- European corn borer, 66, 79, 80
- European starling, 181, 182
- Eustachian tube, of frog, 142
 - of man, 494
- Evaporation of perspiration, effect of, 419
- Evening grosbeak, winter visitant, 161
- Even-toed ungulates, list of, 194
- Evergreen leaves, 299
- Evergreen trees, examples of, 297
 - habitat of, 301
- Exchange of gases, in ameba, 334
 - in blood, 476
- Excretion, a process of all living things, 17, 227, 358, 359
 - in crayfish, 109, 358, 359
 - in fish, 130, 358, 359
 - in frog, 146, 358, 359
 - in grasshopper, 60, 358, 359
 - in hydra, 324, 358, 359
 - in man, 455
 - in paramecium, 334
 - in plants, 227, 231, 358, 359
 - necessity for, 456
 - review of, 358, 359
- Excretory organs of man, 455, 456
- Excurrent stem of evergreens, 236, 237
- Exercise, benefits of, 449
 - necessary to keep one fit, 436
 - out-of-doors, 436
 - systematic, 453
- Exoskeleton, of crayfish, 104, 106
 - of mollusk, 118
- Experiment, on plants, 223, 228, 230
 - to show digestion of starch, 287
- Expiration, 451
- Explosion of fruit case to scatter seeds, 276
- External gills of tadpole, 149
- Extinct animals, remains of, 363-373
- Extinct races of men, 403
- Eyes, compared with camera, 490
 - of fish, 126, 130
 - of grasshopper, 57, 60
 - of man, 488-493
 - of vertebrates, 488
- "Eyes" of potato, 245
- Fabre, Jean Henri, 54
- Fainting, cause of, 450
- Family tree, of animals, 369
 - of plants, 368
- Fangs of rattlesnake, 157
- Far-sighted eyes, 492
- Fascicled roots, 251
- Fat bodies, of frog, 147
- Fat of whale, 202
- Fatigue of muscles, 434, 436
- Fats, a class of foods, 466
 - absorption of, 468, 470
 - formation of, in leaves, 232
 - furnished by animals, 209
 - nutrients, 467
 - use of, 466, 467
- Fear, 157
- Feathers, a characteristic of birds, 164
 - of birds, modifications of skin, 420
- Feces, 456, 470
- Federal and state protection, of birds, 169, 170
 - of forests, 291
- Feeble-mindedness, 510
- Feelers, of bullhead, 130
 - of grasshopper, 57
- Feet of birds, different kinds of, 162, 163
- Fehling's solution, formula, 43
 - test for grape sugar, 43
- Female birds, color of, 165
- Femur, of grasshopper, 59
- Fermentation, 328, 340
- Ferments, 42
- Fern allies, 313
- Ferns, 216, 309-313, 364
 - history of, 309
 - laboratory study of, 314
 - life history of, 310
 - summary of, 320
- Fertilization, defined, 123, 148, 265
 - of egg cell in the ovule, 261, 265, 336
- Fertilizers, 341
- Fibers, in blood, 444
 - of hemp furnish cordage, 246
- Fibrinogen, in formation of clot, 444
- Fibrous roots, 251
- Fibrovascular bundles, cells of, 223, 225, 235, 238, 240, 241
 - conducting vessels, 225, 235
 - in dicotyledonous plants, 238

- Fibrovascular bundles**— *Continued*
 in leaves, 223, 225
 in monocotyledonous plants, 235
 structure of, 223, 235, 238, 241
- Field mice**, eaten by skunks, 190
- Field study**, of conifers, 301
 of moths and caterpillars, 81
- Fig**, a fruit, 278
- Filaments**, of anthers, 258
 of gill, 129
- Finches**, beak of, 163
- Fins**, appendages, 126
 of fish, 127
- Fires**, forests destroyed by, 293, 294, 295
 prevention of, by national government, 294
- Firs**, conifers, 300
- Fish**, 124-139
 enemy of frog, 151
 fish-eating, 127
 fry, 130, 135, 136
 summary of, 138
- Fish hatcheries**, 136
- Fish-killing insects**, 133
- Fission**, a form of cell division, 332, 339
- Flaccid cells**, 226
- Flagella**, 335, 338
- Flat foot**, 439
- Flatworms**, 119
- Flavors**, caused by fermentation and bacteria, 340
- Flax**, useless parts of, removed by bacteria, 340
- Flesh-eating animals**, 189
- Flicker**, a beneficial bird, 167, 177
 at suet station, 184
- Flies**, carriers of bacteria, 84
 classified, 67
 discussed, 84-85
- Floods**, prevention of, 297
- Florist's vocation**, 277
- Flour**, food elements in, 466
- Flowering plants**, 215, 216, 257, 364
- Flowers**, defined, 257
 home work on, 263
 of nasturtium, 258
 parts of, 216, 258
 summary of, 279
 used as medicine, 277
 wind-pollinated, 265
 work of, 261
- Fluorine**, an element in living things, 27
- Fly**. *See* House fly
- Flycatchers**, food of, 94
- Flying mammals** (Chiroptera), 197
- Flying wings of grasshopper**, 58
- Food**, as purchased, 466
 care of, 344
 classes of, 466
 definition of, 466
 fungi, a source of, 325
 groups, 476
 in flowers, 277
 in fruits, 277
 in leaves, 233
 in roots, 254
 in seeds, 288
 in stems, 245
 necessary to keep one fit, 466
 of bacteria, 339
 of bats, 198
 of fish, 127
 of frogs, 142
 of muscles, 433
 of skunks, 190
 of snakes, 157
 storage, 345
 stored in cotyledons of bean, 286
- Food in Drugs Act**, 480
- Food preservation**, 344
- Food standards**, list of, 480
- Food vacuole of ameba**, 331, 332
- Food-fish**, how caught, 137
- Food-getting**, by birds, beaks for, 163
 by grasshopper, 59
 of crayfish, 109
- Foodstuffs**, 286, 287
- Food-taking**, 15-16
 in fish, 127
 in frogs, 142
 not true of green plants, 16
- Food-yolk**, use of, 149
- Foot of clam**, 118
- Foraminifera**, 322
- Fore limbs of animals**, 199
- Forest fires**, 293, 294, 295
- Forest nurseries**, requirements for, 293
- Forest rangers**, work of, 293
- Forest reserves**, 292
- Forester**, duties of, 293
- Forestry**, as a vocation, 293, 545
 in other countries, 292
- Forests**, 291-308
- Formalin**, an adulterant, 479
- Fossils**, 216, 363-373
 where found, 369-373
- Fox**, a carnivorous animal, 189
 protected in New York State, 207

- Fox sparrows**, transients, 161
Fox terrier, comparison of primitive horse with, 194
Foxglove, medicinal plant, 246
Freezing, protection of bacteria from, 339
Fresh air, aid in curing consumption, 513
Fresh fruits, use in diet, 467, 472, 474, 476
Freshets, prevention of, 297
Fresh-water clams, life history of, 118
 uses of, 118
Frog, 141-151
 life history of, 147
Fruit, climax of plant's work, 272, 273
 defined, 272
 dispersal, 274
 dry, 272
 functions of, 273
 growing in the United States, 279
 of apple tree, 5
 of pine, 298, 300
 of rose, 270
 production in connection with storage roots, 253
 purpose of, 273
 steps in development of, 261
 use of, to plant, 277, 282
Fruit flies, 383
Fruiting tips, 319
Fruits, furnish luxuries of food, 277
 use of, as food, 277
 use of word in biology, 277, 282
 with hooks, 275
Fry, fish, 136
Fucus, 319
Fuel, furnished by forests, 291
 trees, source of, 246
Fundamental tastes, 461
Fungal diseases of trees, 294
Fungi, 216, 325-326, 550
Furniture, lumber for, 245, 306, 307
Furs, as clothing, 207
Gall bladder, 143, 460
Gallflies, enemies of apple tree, 2
Game laws, enforced by game wardens, 171
 purpose of, 131
Game preserves, 169
Gametophyte, 313, 315
Game wardens, duties of, 171
Ganglia, of grasshopper, 60
 of sympathetic system, 484
Gardens, injured by rabbits, 193
Gas, a form of matter, 25
 use in bread-making, 328
Gastric glands, 466, 467
Gastric juice, 467
Gastric mill, of crayfish, 109
Geese, domestic birds, 168
 feet of, 163
 open season for, 169
 wild, transients, 161
Genes, 380
Geranium slip, roots of, 243
Germ diseases, 510, 511
Germination, laboratory study of, 286-287
Germs, 338
 a name for bacteria, 338
 of disease carried by insects, 82, 83, 84
Gila monster, poisonous lizard, 157
Gill arches, 128
Gill cover, 126
Gill rakers, 128
Gill scoop, of crayfish, 109
Gill slits, 124
Gills, of crayfish, 109
 of fish, 126
 of tadpole, 149
Ginger root, use of, 254
Ginning of cotton, 289
Giraffe, 189, 200
Girdle, pectoral, 125
 pelvic, 125
Glacier National Park, game preserve, 170
Glands, defined, 466
 in mouth, 459, 466
 with ducts, 496, 497
 without ducts, 144, 496
Glomerulus of kidney, 457
Glucose, 43
Gluten, 467
Glycogen, stored in liver, 433, 435, 470
Gnawing mammals (Rodentia), 189
Goats, 197
 milk of, 470
Goiter, 496
Golden plover, migration of, 181
Goldfinch, discussed, 177
Goldfish, a typical bony fish, 125
Gonium, 335, 336
Gophers, harmful mammals, 205
Grafting, 9

- Grain of wood**, 306
Grains (cereals), 577, 578, 579
Grape, example of berry, 274
 fermentation in juice of, 329
Grape sugar, 27, 43
Grass, monocotyledon, 219, 235
Grasses, adaptations of, 219
 hollow stem of, 239
 importance of, as food, 232
Grasshopper, 55-64
Gravity, a form of energy, 35
 influence of, on roots, 35
Gray substance of nerves, 484
Grease, animal origin of, 209
Great-crested flycatcher, 73
Green algæ, 317, 318
Green frogs, development of, 149
Green glands of crayfish, 110
Green peas as food, 288, 289
Green plants, food factories, 38
 importance of, 215
Green turtles, 156
Green vegetables as food, 472
Grew, early user of microscope, 50
Grosbeaks, beak of, 163
Ground birds, wings of, 163
Growth, dependent on proteins, 466
 of bean embryo, 284
 of bird protection, 169
 of nervous system, 485
 of stems, 242
Grub, enemy of tree, 3
Guard cells of stomata, 226
Guernsey cow, 195, 385
Guinea fowls, domestic birds, 168
Guinea pigs, 205
Gullet, of paramecium, 334
Gulls, food of, 168
 sailing birds, wings of, 163
Gums, effect of tartar on, 462
Guttation, 229
 drops, 229
Gymnosperms, cone-bearing trees, 302
 discussed, 298-303
 economic importance of, 301
 economic value (of forests), 296
 field study, 301
Gypsy moths, injurious insects, 3, 66, 72, 90
Habitat, of evergreens, 301
 of frogs, 141, 151
Habits, 486
 as to alcoholic beverages, 533
 of bats, 198
 of birds, basis of classification, 161
 of frogs, 487
 of skunks, influenced by means of defense, 190
Hæmoglobin in corpuscles, 442
Hair, characteristic of mammals, 188, 419
Hard bone, 430
Hard maple as shade tree, 303
Hard palate, 461
Hard wood of maple, 306
Hardwood trees, 297, 298
Harvestman, useful arachnid, 116
Hatcheries, for lobsters, 111
Haversian canal, 428
Hawk, beak of, 163
 beneficial, 167
 Cooper's, harmful, 168
 foot of, 163
 nest of, 162
 prey upon rodents by day, 168
 red-shouldered, 167
 red-tailed, 167
 sharp-shinned, 168
Hay infusion for Protozoa, 330, 333
Head, body region, 426
 of fish, 125, 126
 of grasshopper, 57, 58
 of vertebrates, 125
Head louse, 81
Head-thorax region of crayfish, 105, 106
Healing of wounds on trees, 303
Health, 506
 activities, 528
 importance of, 509
Health Division of the League of Nations, 526
Hearing, 494
Heart, center in brain, 485
 muscle cells, 433
 of crayfish, 110
 of man, 427, 444
Heat, a form of energy, 33
 a stimulus, 15
 of body furnished by carbohydrates, 466
Heating, flour and meal to kill insects, 70
 milk, effect on bacteria, 344
 protection of bacteria from, 339
Hedgehog, 189
Hemiptera, an order of insects, 66

- Hemlock**, bark, use of, 301
 conifer, 300
 needles of, 300
 soft wood, 300
- Hemorrhage**, 444
- Hemp**, fibers of, 246
- Hemp seeds in attracting birds**, 183
- Herbaceous plants**, 243
- Heredity**, and disease, 524
 and progress, 373, 503, 558
 discussed, 376-395
- Hermit crabs**, 112
- Heron**s, beak of, 163
- Herring**, an edible fish, 125
- Herring gull**, 178
- Hibernation**, defined, 75
 habit of skunk, 190
 of frogs, 151
- Hickory**, source of nuts, 307
 wood, uses of, 304, 307
- Hilum of bean**, 283
- Hind legs of mammals**, 199
- Hinge joint**, 431
- Hinge of clam**, 118
- Hip girdle**, 429
- Hippopotamus**, 194
- Hollow bones of birds**, 164
- Hollow stems of grasses**, 239
- Holly**, use of wood of, 304, 307
- Holstein-Friesian cattle**, 195
- Home study of mammals**, 205
- Home work**, on cereals, 279
 on flowers, 263, 270, 277
 on fruits, 277, 279
 on leaves, 225
 on photosynthesis, 228
 on plant movements, 224
 on pulse rate, 445
 on roots, 254
- Homing instinct in birds**, 183
- Homo sapiens**, 409
- Homoptera**, order of insects, 67
- Honey**, amount of carbohydrate in, 466
 made from nectar, 5
 value of, in United States, 99
- Honeybee**, 94-100
- Hoofed mammals (Ungulates)**, 189, 194
- Hooke**, Robert, 46, 50
- Hooks**, on fruit of burdock, 275
 on fruits, use of, 275
 used to catch food-fish, 135
- Hookworm**, 121
- Hookworm disease**, 121
 distribution of, 526
- Hop lice destroyed by ladybugs**, 74
- Hormones**, 496
- Horned toad**, a lizard, 157
- Horse**, classified, 189
 discussed, 194
 fat, uses of, 209
- Horse-chestnut**, as shade tree, 303
 compound leaves of, 223
 twig, example of woody stem, 240
- Horsetails**, 309, 313, 368
- Host**, 70, 93, 340
- House fly**, 84
- House sparrow (English sparrow)**, 167, 168
 destroyer of insects, 94
 destroyer of larvæ, 94
 discussed, 174
 partly harmful, 168
- Houses of beavers**, 192
- Humane methods**, of catching fish, 137
 of hunting, 202
- Humidity**, significance of, to man's activities, 413
- Humming birds**, beak of, 163
 summer residents, 161
- Humor**, aqueous, 489
 vitreous, 489
- Humus**, a kind of soil, 297
 absorbs water, 297
 formed by leaf decay, 297
- Husks of grain contain minerals**, 474
- Hydra**, cell layers in, 322
 discussed, 322
- Hydrogen**, discussed, 26
 proportion of, in plants and animals, 27
- Hyena**, carnivorous animal, 189
- Hygiene**, of breathing, 452
 of foot, 439
- Hymenoptera (bees)**, 94
 order of insects, 67
- Hyphæ of bread mold**, 325, 327
- Hypocotyl**, curving of, 284
 part of embryo, 283
 use of, to embryo, 284
- Hypopharynx of grasshopper**, 57
- Ice**, a form of water, 25
 use of, in caring for milk, 345
- Ice cream**, 244
- Immigrant pest**, 79
- Immigrants**, quarantine against, 518
- Immovable joints**, 431
- Immunity**, 518

- Immunization, 519
- Imperfect flowers, of corn, 267
- Importation, of aigrettes forbidden, 170
- Incisor teeth, 461
- Incomplete flower, part lacking in, 261
- Incomplete metamorphosis, 61
- Indefinite annual growth, 242
- Indehiscent fruits, 271
- Indian pipe, a leafless plant, 232, 233
- Inflorescence, 259
- Infusion, 330, 333
- Inhalers, 543
- Inheritance, and environment, 394
- Inherited diseases, 510
- Injuries, to eye, 493
 - to teeth, 463
- Inner ear, 493, 494
- Inoculation, 519
- Inorganic foods, 29, 474
- Inorganic matter, 23, 26
- Insanity, 524
- Insect enemies, of fish, 133
 - of forests, 293
- Insecta, 62
- Insect-eating birds, 304
- Insect-eating fish, 127, 128
- Insect-eating mammals (Insectivora), 189
- Insecticides, 70
- Insectivora, a group of mammals, 189
- Insects, 66-88
 - age of, 53
 - agents in distributing pollen, 5, 263, 267
 - characteristics of, 62, 66
 - classification of, 66, 67
 - control of, 69, 72, 77, 81, 304
 - definition of, 62
 - devices of flowers for attracting, 4, 5
 - economic, 54, 67
 - enemies of trees, 304
 - field study of, 81
 - food of bats, 198
 - food of birds, 167
 - food of fish, 127, 128
 - food of frogs, 142
 - food of snakes, 157
 - food of toads, 151, 153
 - in general, 53, 66
 - natural enemies of, 70
 - object in visiting flowers, 5, 263
 - reasons for numbers of, 67
- Inspiration, defined, 451
- Insulin, 497
- Integument, of bean (testa), 282
 - of ovules, 282
- Intermediate stem, 236, 237
- Internal secretion, 396, 397
- Intestinal glands, 466
- Intestine, 427, 456, 464
 - of crayfish, 109
 - of frog, 143
- Invertebrates, group of animals, 124
- Inverted image, 490
- Involuntary muscles, 432
- Iodine, an element found in organisms, 27, 28
 - use of, in foods, 28
- Iodine test for starch, 286
- Iris of eye, 489
- Iron, in blood cells, 29
 - in organisms, 27, 28
 - in prunes and spinach, 29
 - lacking in milk, 472
- Irritability, a fundamental function, 15, 350, 351
 - of hydra, 324
 - of paramecium, 335
 - review of, 350, 351
- Ivy, arrangement of leaves of, 219
 - tendrils of, 223
- Jack-in-the-pulpit, corm of, 260
- Japanese beetle, 72
- Jaw bones of fish, 126
- Jaw of man, 428
- Jellyfish, 324
- Jenner, Edward, 520
- Jersey cow, 195
- Jewelweed, explosive fruit of, 276, 277
- Joints in man, 431
- Jukes family, history of, 393
- Jumping legs of grasshopper, 58
- Junco, a seed eater, 168
 - at seed station, 184
- Kallikak family, history of, 392
- Kangaroo, 189, 200
- Katydid, a family of Orthoptera, 62, 66
- Kidney, described, 455
 - of frog, 146
 - of man, 427, 455
- Kinetic energy, 33
- Kingbird, destroys insects, 74
 - food of, 63, 74, 167
 - migration of, 181
- Kingfisher, nesting habits of, 162

- Knee cap**, 429
- Knees of cypress**, 252
- Koch, Robert**, discoverer of tuberculin test, 346
 - study of bacteria by, 346
- Labium of grasshopper**, 57
- Laboratory study**, of amphibians, 142
 - of appendages of crayfish, 108
 - of apple, 274
 - of bean seed, 286
 - of cells, 47
 - of corn, 287
 - of course of sap, 239
 - of crayfish, 111
 - of digestion of protein and fats, 43
 - of ferns, 314
 - of fish, 127, 142
 - of foodstuffs in seeds, 286, 287
 - of frog, 141, 142, 147
 - of fruits, 273
 - of grasshopper, 56, 58
 - of important substances, 31
 - of land plants, 229
 - of leaves, 225
 - of liberation of gas, 229
 - of liberation of water vapor, 488
 - of live bird, 166
 - of live fish, 127
 - of monarch butterfly, 92
 - of orange, 273
 - of osmosis, 44
 - of oxidation, 42
 - of photosynthesis, 40, 229
 - of reptiles, 159
 - of roots, 252, 253
 - of skeleton, 432
 - of stems, 239
 - of tasting, 461
 - of tomato, 274
 - of transpiration, 230
 - of underground stems, 245
- Labrum of grasshopper**, 57
- Lacey act**, provisions of, 169
- Lacteals**, 470
- Lactic acid**, effect of, 435
- Lady bug**, 74, 75
 - larvæ of, 74, 75
 - natural enemy of cottony cushion scale, 72
- Lake trout**, a fish-eater, 128
 - raised in hatcheries, 137
- Lampreys**, a group of fishes, 125
- Land Carnivora**, 189
- Larch**, a conifer, 301
 - uses made of wood, 307
- Lard**, example of animal fat, 209
- Large intestine**, 143, 459, 464
- Lark, meadow**, nest of, 162
- Larvæ**, 6, 73-85
 - care of, in laboratory, 81
- Larynx of man**, 450
- Lateral bud**, 240
- Laws of heredity**, 382, 503
- Lead**, cause of disease, 510
- Leaf**, 218
 - general structure and parts of, 218, 224
 - modifications, 221
 - mosaic, 219
 - of apple tree, 2
 - outlines, 221
 - scars defined, 240
 - shapes, 221
 - work of, 2
- Leaf-cutting bee**, 3
- Leafless plants**, 233
- Leaflets of compound leaf**, 222
- Lean meat**, example of protein, 467
- Leather**, 208, 209, 210
- Leaves**, arrangement of, 219
 - circulation of, 231
 - compound, 221
 - digestion of, 231
 - excretion of, 231
 - functions of, 226
 - modified forms of, 221, 223
 - movement of, 224
 - of elms, 219
 - of grass, shape of, 219
 - of pine, described, 299, 302
 - of pitcher plant, 223
 - of trees, arrangement of, 219
 - outlines of, 221
 - parts and structure of, 218
 - position of, 224
 - respiration of, 232
 - shedding of, 223
 - simple, 221
 - the plant's factory, 227
 - transpiration, 229
 - used for food, 232
 - used for medicine, 232
- Leech**, enemy of frog, 151
 - segmented worm, 121
- Leeuwenhoek**, 50, 346
- Legs and wings of birds**, 163
- Legumin**, 28

- Leguminous plants help to gather nitrates**, 340
Lemur, 189, 197
Lens of eye, 489, 490, 491, 492
Lenticels, 240
Leopard frog, 141, 149
Lepidoptera, order of insects, 67
Lice, 81, 423
Life cycle, of bean, 284
 of tree, 5
Life functions, 15, 189
Life history, of ant, 101
 of codling moth, 6, 76
 of crayfish, 110
 of eel, 132
 of frog, 147
 of grasshopper, 60
 of house fly, 84
 of malarial parasite, 516
 of monarch butterfly, 90
 of mosses, 315
 of plant, 7
 of potato beetle, 75
 of Pteris, 311
 of reptiles, 155
 of toad, 151
 of Trichinella, 121
Life processes, of bacteria, 339
 of crayfish, 108
 of grasshopper, 55
 of paramecium, 333
 review of, 349-361
Ligaments, 432
Light, a stimulus, 15
 a form of energy, 33
 influence on plants, 33
Lightning, cause of forest fires, 294
Lily, parallel venation in, 219
Limbs of man, 429
Linden tree, 303, 307
Linen, furnished by flax, 245
 source of clothing, 245
 use of bacteria in manufacturing, 340
Lingula, 362, 363
Linseed cake, source of, 289
Linseed oil, source of, 289
Lion, a carnivorous animal, 189
Lipoid, 535
Liquid, a form of matter, 25
Lister, Sir Joseph, 527
Liver, 427, 466
 of crayfish, 109
 of frog, 143
Lizards, color of, an adaptation, 159
 discussed, 156
 example of reptile, 155
 horned toad, example of, 157
Llama's milk, 470
Lobes, olfactory, 145
Locust, example of Crustacea, 104
 protected by law, 111
Locomotion, of fish, 127
 of hydra, 323
 of paramecium, 333
Locust, a kind of grasshopper, 62
Locust wood, 305
Locusts, plague of, 62
Longitudinal arch of foot, 439
Lookouts in fire prevention, 293
Louse, carrier of disease, 82
Lumber, chief product of forests, 291, 296
 from gymnosperms (conifers), 301
Lumbering, 294
Lungs, of birds, 164
 of frog, 144
 of man, 427, 451
Lymph, 448
Lymphatic circulation, 449
Lymphatic vessels, 449
Lynx, a carnivorous animal, 189

Mackerel, a bony fish, 125
Magnesium, element found in living things, 27
Mahogany, use of, as furniture, 307
Malaria, 511, 515
Malarial parasite, 515
Male birds, color of, 165
Malpighi, 50
Mammal sanctuaries, 203
Mammals, adapted to marine life, 189
 best developed brains of, 188
 characteristics of, 188
 classified, 189
 discussed, 188
 hibernation of, 190
 home studies on, 205
 sanctuaries for, 203
 special adaptations of, 199
 summary of, 210
 the rulers of the earth, 188
 valuable for oil, 209
 warm-blooded animals, 188
 with nails (Primates), 197
Man, and his competitors, 11
 as an animal, 374, 406
 classification of, 189, 406

- development of, 503
- example of mammal, 189
- heredity, 503
- independent of environment, 412
- learning of, 504
- power of adaptation of, 409
- origin of, 502
- prehistoric, 403-406
- superiority of, 412
- Mandibles**, of crayfish, 107
 - of grasshopper, 57
- Mandrake**, medicinal plant, 254
- Maple trees**, 303, 306, 307
- Maple wood**, use of, 306, 307
- Marchantia**, 316
- Mare's milk**, 471
- Margarine**, example of animal fat, 209
- Marine turtles**, adaptations in, 159
- Marsupials** (pouched animals), 189
- Martins**, 83
- Massasauga**, a rattlesnake, 157
- Matter**, organic and inorganic, 23
- Maxilla**, of crayfish, 107
 - of grasshopper, 57
- Maxillipeds**, of crayfish, 107
- May beetle**, harmful insect, 74
- Meadow lark**, nest of, 162
- Measles**, a contagious disease, 511
 - probable cause of, 511
- Meat**, lean, use of, as food, 466, 467
 - sources of, 195, 196, 197
- Median fins of fish**, 126, 127
 - balancing organs, 127
- Medicinal plants**, 232, 246, 254
- Mediterranean fruit fly**, 383
- Medulla**, of frog, 145
 - of man, 484
- Medullary rays of woody stem**, 241, 299
- Medullary sheath of nerve**, 484
- Mendel, Gregor Johann**, experiments
 - with peas, 381
- Mendelian Laws**, 382
- Mending broken bones**, 431
- Menhaden**, example of bony fish, 125
- Mental attitude**, effect on posture, 438
- Mental health**, 524
- Mercury poison**, 510
- Mesentery of frog**, 143
- Mesoglæa of hydra**, 322
- Mesophyll of leaf**, 225
- Mesothorax of grasshopper**, 58
- Mesozoic period**, 366, 367
- Metamorphosis**, 61
 - complete, 90
 - incomplete, 61
 - of frog, 149
- Metathorax of grasshopper**, 58
- Mexican bean beetle**, 66, 72
- Mexican fruit fly**, 72
- Mice**, destroyed by hawks, 167
 - destroyed by shrikes, 168
 - destroyed by snakes, 157
 - harmful mammals, 191
- Microbes**, a name for bacteria, 338
- Micropyle**, of bean, 282
- Microscope**, inventor of, 49
- Midbrain**, function of, 145
 - of frog, 145, 484
- Middle ear**, 494, 495
- Migration**, of birds, 161, 171, 180
 - of monarch butterfly, 91, 92
- Migratory bird treaty act**, 169
- Milk**, as a food, 470-472
 - care of, 344-346
 - curd of, example of protein, 467
 - nutrients in, 472
 - substances lacking in, 472
- Milk glands**, characteristic of mammals, 188
- Milk products**, 345
- Millipedes**, 117
- Milt of fish**, 136
- Mimicry in insects**, 83
- Mineral matter in food**, 28, 466, 472, 474
- Mineral tan**, 209
- Mining bee**, 55
- Mink**, carnivorous animal, 189
 - harmful mammal, 190
- Mints**, rhizomes of, 246
 - used for medicine and in food, 232
- Mites**, arachnids, 116
- Mixed joints**, 431
- Mixture**, 24
- Modified cotyledon (scutellum) of corn**, 285
- Modified fore-limbs of mammals**, 199
- Modified leaves**, 223
- Modified stomach of ruminants**, 194
- Moisture**, a condition for growth of
 - bacteria, 339
- Molars of man**, 461
- Moles**, 189
 - destroyed by hawks, 167
- Mollusks**, 118
- Molting**, of crayfish, 105
 - of grasshopper, 61
- Monarch butterfly**, 90

- Mongolian or yellow men**, 420
Monkey, example of Primates, 189, 197
Monocotyledonous stems, 235, 242
Monocotyledons, 235
Morning-glory, an annual plant, 243
Mosaic vision, 108
Mosquitoes, breeding places, 82
 enemies of, 83
 kinds in United States, 83
 life history, 83
 members of Diptera, 67, 82
 methods of control, 83, 84
Mosses, flowerless plants, 216, 311, 314, 364
 habitat, 315
 life history, 315
 related plants, 316
 study of, 316
Moths, example of Lepidoptera, 67
Motion, a form of energy, 34
 a fundamental function, 15
 compared, in organic and inorganic, 16
 in ameba, 331
 influence on organisms, 34
 review of, 352
Mountain Lake Sanctuary, 171
Mourning cloak butterfly, 81
Mouse, 189, 191
Mouth of man, 459, 461
Mouth parts, of butterfly, 91
 of caterpillar, 91
Movable joints, 431
Movement, of fish, 127
 of leaves, 224
Mucous glands of fish, 126
Mulberry leaves, used as food for silk-worms, 78
Mule, 194
Mullein, flowers of, 277
 leaves of, used for medicine, 232
Muscle bundle, 432
Muscle cells of heart, 433
Muscle fibers, 432
Muscles, 432-436
 controlled by cerebral hemisphere, 145
 fatigue of, 436
Mushrooms, edible fungi, 325, 326, 550
 poisonous, 327, 511
Muskrat, 191
Mustard seeds used as medicine, 289
Mutation, 384
Mutton tallow, use of, 209
Myosin, 28
Myriapods, 116
Nails, characteristic of Primates, 197, 422
 origin of, 422
Narcotic, defined, 532
 effects of, on digestion, 535
 examples of, 532
Narrow-leaved (soft) woods, 297
Nasal cavity of fish, 130
Nasturtium flower, example of adaptations, 267
 parts of, 258
National Association of Audubon Societies, 171
National forest preserves, 292
National game preserves, 170
National quarantine, 518
Native fruit, 8
Natural enemies, of potato beetle, 75
 use of, in controlling insects, 70, 72
Natural gas, formation of, 310, 369
Natural immunity, 519
Near-sighted eyes, 492
Neck, of giraffe an adaptation, 200
 of tooth, 462
Nectar, 5, 258
Nectar glands, 260
 use in blossom, 5
Needle-like leaves of pine, 299
Nerve cells, 483
Nerve fibers, 483
Nerve pathways, 483
Nerves, in muscles, 433
 of crayfish, 110
 of frog, 144, 147
Nervous system, comparison of crayfish, fish, and frog, 145
 growth of, 485
 most complicated structure, 482
 of crayfish, 110
 of fish, 130
 of frog, 144
 of grasshopper, 60
 of man, 482
 parts of, 145
 summary of, 500
Nest-building of birds, 165, 172
Nesting boxes, 184, 185
Nesting habits a basis of classification, 162
Net-veined leaf, 219
Neurons, 483
Nicotine, a narcotic, 533
Nighthawks, destroyers of mosquitoes, 93

- Nitric acid test for protein**, 286
Nitrogen, a chemical element, 27
 cycle, 341, 343
 gathered by bacteria, 340
 proportion of, in living things, 27
 supplied by decay of dead organisms, 340
 supplied by excretions of living things, 340
 taken from air for fertilizer, 341
 taken from soil by crops, 340
Nodules on roots of leguminous plants, 341
Non-smokers, 543
Normal body temperature of man, 444
Northern shrike, winter visitant, 161
Nose, sense organ, 488
Novius, enemy of cottony cushion scale, 72
Nucellus, 282
Nuclei of pollen and egg, 264
Nucleoli of cells, 46
Nucleus, of cell, 46, 331, 333
 of nerve cell, action of alcohol upon, 535
Nurses, 545
"Nurses," care of bee larvæ by, 96
Nut, use of word in biology, 278
Nuthatches, at suet station, 184
 destroyers of eggs of insects, 94
Nutrients, defined, 27
 in common foods, 466
 in milk, 472
 named, 27
 use of, 467
Nutrition, a fundamental function, 17
 of ameba, 331
 of hydra, 324
 of paramecium, 334
 phases of, 17
 review of, 354
 uses of nutrients in the body, 467, 472
Nuts, from hardwood trees, 307
 furnished by walnut, 307
Nymphs, of cicada, 73
 of grasshoppers, 60

Oak trees, 303, 306
Oat plant, root system of, 251
Oats, a cereal, 277
Odd-toed ungulates, 194
Odonata, order of insects, 67
Odor, of skunk, mink, and weasel, 190
Oils, a class of foods, 27
 definition of, 209
 found in seeds, 286, 289, 310
Olfactory lobes, of frog, 145, 147
One-celled plants, 326
Open seasons for game birds, 169
Operculum of fish, 126
Opium, 510, 532, 538-539
Opossum, 189, 202
Optic lobes of frog, 145
Optic nerve, 491
Orbits, 488
Orders, groups in classification, 66, 567
Organ, defined, 48
Organic ash, 31
Organic matter, 23
Organism, beginning of new, 373
 defined, 23
 sensation in, 15
Orioles, destroy cocoons, 94
 discussed, 174
 protected by law, 169
Ornithologists' Union, American, 171
Orthoptera, order of insects, 62, 66
Osage orange leaves, food for silkworms, 78
Osmosis, defined, 43
 demonstration of, 44
 factor in movement of sap, 231
 in absorption of food, 469
 in photosynthesis, 43
 in root hairs, 252
Osprey plumes, importation forbidden, 170
Ostrich plumes, 170
Otter, a carnivorous mammal, 190
Outer ear, 493
Outer skeleton, of crayfish, 104
 of turtle, 155
Ovary, of frog, 146
 part of pistil, 258, 259, 261
Overeating, results of, 456
Oviducts of frog, 146
Ovipositor of grasshopper, 58
Ovule-bearers in pine, 300
Ovules, change to seed in, 282
 found in ovary, 261
 in pine, 300
Owl, feet and beak of, 163
 preys upon rodents at night, 180
 screech, beneficial, 167, 180
 snowy, a winter visitant, 161
Oxalis, sleep movements of, 224
Oxen, 196
Oxidation, in birds, 164

Oxidation — *Continued*

physical, 42

physiological, 41

Oxygen, a chemical element, 26

a condition for the growth of bacteria, 339

a waste of photosynthesis, 228, 232
cycle, 341, 342

proportion of, in living things, 26

use in respiration, 17, 227, 228

Oysters, examples of mollusks, 118

source of iodine, 28

Paint used on trees after pruning, 303**Paintbrush**, an annoying weed, 270**Palate of man**, 459**Paleozoic period**, 366, 367, 368, 369**Palisade cells of leaf**, 225**Palm**, example of monocotyledon, 235**Palmately compound leaves**, 222**Panama Canal**, a health problem, 516**Pancreas**, of frog, 143

of man, 466, 468, 496, 497

secretions of, 468, 497

Pancreatic juice, changes caused by, 468**Panicle**, 259**Papillæ of tongue**, 461**Pappus**, 275**Parallel venation**, 219**Paramecium**, described, 333

example of Protozoa, 333

life processes, 333

mode of defense, 333

study of, 333

Parasites, action of, 81, 85

group of fungi, 326

tapeworms, 119

Thalessa, 86

that injure hides, 209

Parasitic flies, 86

enemies of moths and butterflies, 93

Parasitic root, 251**Parasitism**, a dependent relation, 85**Parathyroid glands**, 496**Parks**, development of, 292**Parrots**, can be trained to speak, 168

caught wild, not bred, 169

Parsnips, example of biennial, 253

storage of food in, 255

Partridge, wings of, 163**Passive immunity**, 519**Pasteur**, Louis, discoverer of lactic acid bacteria, 346

researches of, 527, 528

study of bacteria by, 346

Pasteurization, defined, 344

effect of, 344, 346, 527

Pasteurized milk, 344**"Patent" medicines**, defined, 539

to be avoided, 539

under Food and Drugs Act, 480

Pea plant, member of pulse family, 288

modified leaves of, 223

produces protein, 288

Peach, example of drupe, 274**Peacocks**, domesticated birds, 168**Peanut**, source of calcium and phosphorus, 29**Peanut shucks as adulterant**, 479**Pectoral fins**, 126, 127**Pectoral girdle**, of vertebrates, 125**Pellets of owl**, 167**Pelvic fins**, 126**Pelvic girdle**, of vertebrates, 125**Penguins**, use of wings, 163**Peppermint leaves**, used for flavor, 232

used for medicine, 232, 246

Pepsin, an enzyme, 43**Perch**, a bony fish, 125

an insect-eating fish, 128

Perennial roots, 253**Perfect flower**, definition of, 260**Permanent teeth**, 462**Petals**, described, 4, 258, 259

function of, 261

Petiole, of clematis, 221, 223

of leaf, 218

Pharynx, of man, 463**Pheasant**, 168

food of, 74, 167, 168

wings of, 163

Phlegmatic temperament, heart tracing of, 543**Phloëm**, conducting food materials, 231

discussed, 238

part of vascular bundle, 223

position of, in vascular bundle of woody stem, 238

Phœbes, destroy insects, 94

discussed, 178

Phosphorus, a chemical element found

in living things, 27, 28

a poison, 510

in peanuts, 29

useful in body, 29, 474

Photographing wild flowers, 548, 556**Photosynthesis**, a life process, 227

- defined, 39, 227
- discussed, 38, 39
- finished product of, 228
- importance of, 39
- oxygen produced by, 39, 228
- performed by stem, 244
- use made of products of, 228
- vital process in green plants, 40, 227
- Phylloxera**, injurious insect, 379
- Physical change** described, 25
- Pickarel**, a fish-eater, 128
- Pigment** in skin, 421
- Pigs**, 189, 194
- Pike**, a bony fish, 125
 - a fish-eater, 128
- Pine**, seed, wing of, 300
 - soft wood tree, 298
 - tree, described, a type, 298
 - yellow, lumber of, 304
- Pineal gland**, 497
- Pink boll worm** of cotton, 66
- Pistil**, described, 258, 259
 - function of, 261
- Pistillate flower**, 259
- Pitch**, source of, 301
- Pitcher plant**, 223
- Pith**, in corn stem, 238, 241
 - in woody stem, 240, 241
- Pituitary gland**, 497
- Plague**, an epidemic disease, 82
- Plague of locusts**, 62
- Planarian worm**, 119
- Plant biology**, 215
- Plants**, as organisms, interest in, 216
 - breeding of, 373, 374, 385-390
 - general structure of, 216
 - lice on, 100
 - respiration of, how studied, 232
 - without leaves, 233
- Plasma**, 442, 443
- Pleurococcus**, 329
- Plum**, example of drupe, 274
- Plumage**, 164
- Plumes** on wind-distributed seeds, 275
- Plumule**, connection with seed leaves, 283
 - development of, 284
- Pod**, form of fruit, 276, 271
- Poison**, defined, 532
 - examples of, 532
 - in tobacco smoke, 541
 - spray used to kill insects on trees, 294
- Poisoning**, method of controlling insects, 70
- Poisonous fungi**, 326, 327, 511
- Pollen cell**, characteristics of, 265
 - described, 264
 - distributed by wind, 265
 - necessary for producing seed, 263, 264
 - of pine, air sacs of, 300
 - part of flower, 5, 258
 - produced by stamens, 261
 - tube, 264, 265
- Pollen grains**, structure of, 264
 - variety in, 265
- Pollen-bearing organs** of pine, 299
- Pollination**, by wind, 265
 - definition of, 5, 263
 - service of bee in, 5
 - step in production of fruit, 263
- Pome**, 271
- Poplars**, as shade trees, 303
 - excelsior obtained from, 307
- Porcupine**, 189, 191
- Pork**, *Trichinella* in, 121
- Portal circulation**, 448, 469
- Potassium**, a chemical element found in
 - all living things, 27
 - contained in food, 29
 - use in body, 475
 - use to plants, 29
- Potato**, a food plant, 245
 - stem of, 244
 - underground stem of, 244, 245
 - used for storage, 241
- Potato beetle**, 74-76
- Potential energy**, 33
- Pouch** of kangaroo, 200
- Pouched mammals**, 189
- Poultry** destroyed by certain hawks, 168
- Præcocial birds**, defined, 165
- Prairie dogs**, destroyed by hawks and owls, 167
- Prairie horned larks** at seed station, 183, 184
- Preservation of wood**, 305
- Preservatives**, list of, 345, 347
 - use of, in milk, 345
- Preventable diseases**, 511
- Prevention**, of communicable diseases, 511, 517, 521
 - of epidemics, 523
 - of floods and freshets, 297
 - of forest fires, 293
 - of malaria, 517
 - of sickness, 511, 517
- Primary roots**, 284

- Primates**, group of mammals, 189, 197, 406
- Proboscidia**, 189
- Procumbent stems**, 237
- Products**, made from trees, 306-308
 of cotton seeds, 289
 of photosynthesis, 227, 228
- Prone pressure**, a method of respiration, 454
- Propagation by slips**, 243
- Propolis**, defined, 98
 use of, by bees, 98
- Prop root**, 251
- Protection**, of birds, 169-171
 of buds, 240
 of fish, 135
 of forests, 291
 of grasshopper, 56
- Protective coloration**, of birds, 165
 of crayfish, 105
 of insects, 86
- Protective resemblance**, 86
- Protein**, a class of foods, 27, 28, 228, 466
 foods repair muscles, 433
 in bean, 287
 in corn, 287
 lean meat example of, 467
 stored by bean, 287
- Prothorax of grasshopper**, 57
- Protoplasm**, of cell, 17, 46, 49
 of pollen grain, 264
- Protozoa**, paramecium an example of, 333
 reproduction of, 335
 response to stimuli of, 335
- Protozoan culture**, directions for making, 330
- Prunes**, source of iron, sodium, potassium, and phosphorus, 29
- Pruning**, 303
- Pseudopodium of ameba**, 331
- Pteris**, 310-313
 leaves of, 310
 life history of, 311
 stem of, 311
- Ptyalin**, an enzyme, 463, 467
- Public health activities**, 525
- Public museums**, 185
- Public parks**, 170, 292
- Public preserves**, 292
- Puffballs**, a form of fungus, 326
- Pulmonary circulation**, 446
- Pulmonary tuberculosis**, 512
- Pulse caused by beating of heart**, 445
- Pulse family**, foods furnished by, 288
 value to the soil of the plants of, 340, 341
- Pupa**, stage in the metamorphosis of insects, 6, 9
- Pupæ of insects eaten by birds**, 94
- Pupation**, 78
- Pupil of eye**, 489
- Pure culture**, 346
 of nitrogen-gathering bacteria, 343
- Pure food laws**, 481
- Pyloric valve of stomach**, 464
- Python**, a constrictor, 157
- Quack**, 524
- Quack grass**, 244
- Quail**, 74, 167
- Quarantine**, against insects, 81, 517
 defined, 517
 laws, 518
- Quarter-sawn timber**, 306
- Queen bee**, 94, 96, 99
- Rabbits**, destroyed by hawks and owls, 167
 destroyed by snakes, 157
 eaten by skunks, 190
 enemies of, 193
 food of, 193
 gnawing mammals, 189
 groups of, 193
 harmful animals, 193
 protection of trees from, 193
- Raccoon**, 189
- Raceme**, 259
- Radial sections of wood**, use of, 305
- Radiolarians**, 364
- Railroad ties**, preserved by chemical, 306
 use of trees for, 246
- Rails**, open season for, 169
- Raisins attractive to birds**, 183
- Raspberry, black**, uses stem for propagation, 241
- Rats**, destroyed by snakes, 157
 discussed, 192
 gnawing mammals, 189
 harmful animals, 192
 pests, 192
- Rattlesnake**, fangs of, 157
 poison, effect of, 511
 poisonous, 157
- Raw milk**, danger from, 344
- Ray flowers of composites**, 259, 263

- Receptacle**, function of, 261
 part of flower, 260
Recessive characters, 382
Rectum, part of digestive system, 465
Red corpuscles of blood, 442, 515
Red Cross, 527
Red-eyed vireo, migration of, 181
Redpoll, a seed-eater, 168
Red-shouldered hawk, useful bird, 167
Red-tailed hawk, useful bird, 167
Reduced stems, 237
Red-winged blackbird, food of, 63, 167
Redwood trees, age of, 243
Reflex action, 486, 487
Reforestation, 292-294
Refrigeration of foods, 345
Regular flowers, 260
Reindeer, economic importance of, 204
Rejuvenation of worn-out land, 297
Relapsing fever, germs of, 82
Repair dependent on proteins, 466
Reproduction, a life process, 18, 360
 asexual, 324
 of ameba, 332
 of bacteria, 339
 of fish, 130
 of frogs, 146
 of grasshopper, 60
 of hydra, 324
 of paramecium, 335
 of yeast plant, 328
 review of, 360
 sexual, 324
Reproductive glands, internal secretions of, 497
Reproductive hyphæ of bread mold, 326
Reproductive organs of man, 427
Reptiles, adaptations of, 158
 cold-blooded animals, 158
 discussed, 155
 life history of, 155
 summary of, 159
Residents, birds classed as, 161
Resin, decay-resisting substance, 305
 source of, 301, 307
Resistance, of body to disease, 518
 of grapes to disease, 378
Respiration, a fundamental function, 17, 226
 described, 17
 in man, 450-454
 means of obtaining energy, 17, 450
 of ameba, 332
 of crayfish, 109
 of fish, 129
 of frogs, 144, 149
 of grasshopper, 59
 of hydra, 324
 of paramecium, 334
 of plants, 218, 226, 232
 of toad tadpoles, 152
 produces carbonic acid gas, 17
 purpose of, 17
 review of, 356
 student report on, 450
Rest, effect of, in consumption, 513
 relieves fatigue, 487
Restricted diet of primitive life, 466
Retina, 489
Rhinoceros, 189
Rhizome, 237
Rhubarb, medicinal plant, 254
Ribs of man, 428
Rice, a cereal, 277
Rickets, prevention of, 476
Rind of corn stem, 239, 242
Ring-necked pheasant destroys beetles, 74
Rings, on cross section of pine stem, 298
 on horse-chestnut twig, 240
Robber bees, 98
Robin, 174
 a useful bird, 174
 destroys white grubs, 74
Rochelle salts in Fehling's solution, 43
Rockefeller Foundation, 526
Rockweed, 319
Rodentia, 189
Rodents, carriers of germs, 82
 defined, 82
 discussed, 191-193
 eaten by hawks and owls, 167
Rod-shaped bacteria, 338
Rookeries of crows, 173
Root, of corn embryo, 286
 of tooth, 462
 part of plant, 1, 3, 249
Root cap, 250
Root hairs, discussed, 252
 size of, 252
Root pressure, 231
Root system, influence of soil and moisture on, 249
 of alfalfa, 253
 of wheat plant, 253
Rootlets, 250
Roots, functions of, 249
 help to hold soil, 297

Roots — Continued

- length of, 253
- of beet, 255
- of pine, 299
- structure of, 250
- Rose protected by thorns, 242
- Rose-breasted grosbeak, destroyer of potato beetles, 74
- Rosette formation of leaves, 219
- Rotation of crops, in controlling insects, 69
- Roundworms, 120
- Rubber, list of articles made from, 308
- Rudimentary toes of horse and cow, 199
- Ruminants, 194
- Runner, 237
- Russian thistle, the distribution of, 275
- Rye, a cereal, 277

Saffron, source of, 277**Sage, leaves of, for flavoring, 232****Sailing birds, examples, 163****Salamander, classified, 140**

- largest amphibian, 140

Saliva, of mosquito, 516

- use of, in man, 459, 463, 467

Salivary glands, of man, location of, 352

- of mosquito, 516

Salmon, example of bony fish, 125

- migration of, to spawn, 131

Salt, a fundamental taste, 461

- use of, in preserving meat, 345

Sand swallow, nest of, 162**Sand worm, a segmented worm, 121****Sandpipers, open season for, 169****Sandy soil favored by evergreens, 301****Sanitation, effect of, in preventing disease, 510****Sap, 231****Saprophytes, group of fungi, 326****Sawdust, adulterant, 479**

- use of, 307

Sawflies, example of Hymenoptera, 67**Scale insects, example of Homoptera, 67****Scales, of fish, 126**

- of horse-chestnut bud, 240

- of snakes, 157

- of staminate cone of pine, 299

Scarlet fever, a contagious disease, 511

- probable cause of, 511

Scars, characteristic of stem, 240**Scavengers among birds, 168****Sclera, 489****Sclerotic coat of eye, 488****Scorpions, example of Arachnida, 115**

- 116

Scouring rushes, 309, 314**Screech owl, a useful bird, 167**

- discussed, 180

Scurvy, cause of, 476**Scutellum, digestive organ of corn grain, 285****Scutes of snake, 157****Sea cucumbers, 117****Sea lion, aquatic carnivorous animal, 189****Sea turtles, 156****Sea urchins, 117****Sealing, object of, in canning, 345****Seals, 189****Seasoning of wood, 305****Secretin, 497****Seed, 282**

- adaptations of, 283

- coat of, 282

- development of, 283

- distribution of, 274

- of pine, 300

- production of, object of plant, 257

- roots, 284

- use of word in botany, 278, 282, 288

"Seed" corn, 278**"Seed" wheat, 278****Seed-eating birds, 163, 168****Seed-leaves, 1****Seedling, 284****Seed-producing organs of pine, 299****Seeds, as food, 286**

- devices for distributing, 274

- food of birds, 167, 168

- improvement in, by cross-pollination, 267

- of cotton, 289

- used as medicine, 289

- variety in, 284

Segmented worms, 121

- earthworms, 121

Segments, of crayfish, 105, 106, 110

- of grasshopper, 59

- of worms, 121

Segregation, law of, 382**Selaginella, 309****Self-pollination, discussed, 266**

- prevention of, 266

Sensation, a life process, 15

- review of, 350

Sense of direction in birds, 183**Sense organs, 488**

- Sepals**, described, 258, 259
 function of, 260
Setting of bones, 431
Seventeen-year locust (cicada), 72
 bird enemies of, 73
 life history of, 73
Sewage, contains typhoid germs, 84
Sewer pipes clogged by roots of trees, 303
Sexual reproduction, 324
Shad, example of bony fish, 125
 spawning habits of, 131
Shade trees, 303
Sharks, a division of fishes, 125
Sharp-shinned hawk harmful, 168
Sheep, discussed, 196
 even-toed ungulate, 194
Shocks, effect of, 485
Shrew, 189
 eaten by birds, 167
Shrikes, 167, 168
Shrimps, example of Crustacea, 112
Sieve plates, 238
Sight, 490-493
Silica in corn stem, 239
Silicon, an element in living things, 27
Silk of corn, 267
Silkworm, 78
Silver maple, poor shade tree, 303
Simple eyes of insects, 57
Simple leaf, 218, 219
Sinuses of crayfish, 110
Sirup, maple, 307
Sitting, correct posture for, 437
Skeletal structures, student report on, 432
Skeleton, of birds, 164
 of crayfish, 104, 105, 106
 of mammals, 199
 of man, 427, 439
 of turtles, 155
Skeletonizer, 2
Skin, as sense organ, 488
 discussed, 417-424
 organ of respiration in frog, 144
Skull of man, 426, 427, 428
Skunk, destroys potato beetles, 76
 example of beneficial mammal, 190
 farms, 191
 habits of, 190
Sleep, and relaxation, 487
 appearance of, by plants, 224
"Slipping," a method of propagation, 243, 244
Slips producing adventitious roots, 252
Sloth, 189
Slugs, eaten by toads, 151
Small intestine, of frog, 143
 of man, 456, 459, 464, 468
Smallpox, 520
Smell, relation to taste, 488
 sense of, 488
 stimuli received by olfactory lobes, 145
Smilax, tendrils of, 223
Smoke poisons, 544
Smoker's heart, effect of tobacco illustrated, 542, 543
Snails, food of fish, 127
 food of frogs, 142
Snakes, beneficial animals, 157
 discussed, 157
 enemies of frog, 151
 enemies of potato beetle, 76
 examples of Reptilia, 155
 scales of, 157
Snapdragon, spur on, 260
Snapping turtle, 156
Snowy owl, a winter visitant, 161
Soap, source of oils for, 209
Society for the Prevention of Cruelty to Animals, 203
Sodium, a nutrient, use of, 29
 found in prunes, carrots, and spinach, 29
 use of, in body, 474
Soft palate of man, 461
Soft-wood trees, 297
Soil, and development of root system, 249
 upper layers, habitat of bacteria, 340
Soil bacteria, 340
Soldiers, a class of ants, 100
Solid, a form of matter, 25
Solitary flower, 259
Song sparrow, at hemp and millet station, 184
 discussed, 176
 useful bird, 167, 168
Sounds from sound waves, 493
Sour, a fundamental taste, 461
Souring of milk, cause of, 344
Southern cattle tick, extermination of, 209
 injures skins, 209
Soy bean, valuable for food, 288
Sparrow, house (English), 174
 destroyer of cicadas, 74

- Sparrow, house** — *Continued*
 example of useful bird, 167
 fox, example of transient bird, 161
 seed-eater, 174
- Sparrow hawk**, 63
- Spawning habits**, 130, 131
- Spearmint**, uses of, 232
- Specialization of the nerves**, 483
- Specialized stems**, 237, 244
- Sperm**, cells of fishes, 130
 nucleus of pollen grains, 264
 of hydra, 324
 of Volvox, 336
- Spermary of frog**, 146
- Sphinx moth from tomato "worm,"** 81
- Spiders**, arachnids, 115
- Spike**, a form of inflorescence, 259, 262
- Spinach**, source of iron and sodium, 29
- Spinal column of man**, 425, 428
- Spinal cord**, part of nervous system, 482
 source of nerves, 145
- Spinal nerves of frog**, 145
- Spines of porcupine**, 202
- Spiracles of grasshopper**, 58, 59
- Spiral arrangement of leaves**, 219
- Spirillum**, a form of bacterium, 338
- Spirogyra**, 318, 364
- Spleen of frog a ductless gland**, 144
- Splints**, use of, in setting bones, 431
- Spoiling of food by bacteria**, 340
- Sponges**, 336
 use of bacteria in preparation of, 340
- Spongy bone**, 429
- Spores of bread mold**, 326, 327
- Sport**, 384
- Sprain**, defined, 432
- Spruce**, cone-bearing tree, 300
 needles of, 302
 soft wood of, 300
- Spur**, part of flower, 258, 260
- Sputum**, destruction of, necessary, 512
 spread of tuberculosis by, 512
- Squirrels**, adaptation of, 200
 rodents, 189, 191
- Stable fly**, harmful insect, 82
- Stalk borer**, 80
- Stalk of corn**, monocotyledonous stem, 235
- Stamens**, function of, 261
 part of blossom, 5, 258, 259, 261
- Staminate cones of pine** (pollen bearers), 299
- Staminate flower of corn**, 267
 of willow, 259, 266
- Standing**, correct posture of, 438
- Starch**, a nutrient, 27
 form of carbohydrate, 467
 found in bean and corn, 286, 287
 found in potatoes, 245
- Starfish**, 117, 417
- Starling**, migration of, studied, 181
- State conservation of birds**, 170
- State parks and game preserves**, 170, 203, 291-292
- State protection of birds**, 170
- State protection of forests**, 291
- Stations** (lookouts), 293
- Steam**, a form of water, 25
- Stegomyia**, a mosquito (*Aedes*), 83
- Stem**, adaptations of, 241
 as a means of propagating plants, 241, 243
 cross section of pine, 298
 dicotyledonous, 238
 duration of, 243
 functions of, 235, 241
 in a double rôle, 235
 monocotyledonous, 235
 of cactus plants, 244
 of conifer, 298
 of corn, 239
 organ of circulation, 235
 part of plant, 1, 3
 two kinds of, 235
 uses of, to plant, 3
 woody, study of, 240
- Sternum**, of man, 428, 429
- Sticklebacks**, nests of, 131
- Stigma**, feathery, 265
 of saffron crocus used as dye, 277
 part of pistil, 9, 258, 261
- Stimulants and narcotics**, 532
- Stimuli**, defined, 15
- Sting of bee**, 96
- Stinging cells of hydra**, 323
- Stipules**, part of leaf, 218, 221
- Stolon**, roots, 252
- Stomach**, a digestive organ, 459, 464
 example of organ, 48
 of crayfish, 109
 of frog, 143
 of man, 427, 464
 valves of, 464
- Stomach poison to kill insects**, 70
- Stomata**, 224, 225
- Storage of food**, in leaves, 218, 227
 in stems, 241
- Strap-shaped flowers**, 262

- Strawberry**, propagation, 241, 252
Strobilus, 314
Street cleaning by flushing, advantage of, 512
String beans, value of, as food, 289
"Strings" of celery, 223, 225
Structure, of ameba, 330, 331
 of birds, 164
 of bone, 429
 of fish, 125
 of leaves, 218
 of man, 426
 of monocotyledonous stem, 239
 of paramecium, 333
 of pollen grain, 264, 265
 of roots, 250, 252
 of stomata, 226
 of tooth, 462
 of vascular bundle, 235
 of woody stems, 240
Style, adaptations of, 265
 part of pistil, 258, 261
Subcutaneous layer, 418, 419
Sucker, an insect-eating fish, 128
Suet, for winter feeding of birds, 183
Suet-eating birds, 184
Suffocation, and artificial breathing, 301
Sugar, a nutrient, 27
 a preservative, 345
 broken up by yeast enzyme, 327
 form of carbohydrate, 286
 found in bean and corn, 286, 287
 in liver, 433
 obtained from maple trees, 307
 product of photosynthesis, 39
 value of, as food, 473
Sulfur, an element in animal and vegetable tissues, 27
Summer residents, examples of, 161
Sundew, use of leaves in, 223
Sunfish, care of eggs by, 131
 example of bony fish, 125
Sunflower, "seed" at feeding station for birds, 183
Suprarenals, 497
Surgery, 527
Surplus food stored in roots, 255
Sutures of bone, 431
Swallows, destroyers of flying insects, 177
 protected by laws, 169
Swallow-tail butterfly, from celery worms, 81
 larvæ of, 90
Swans, open season for, 169
Swarming of bees, 98
Sweat glands, 418, 455
Sweet, a fundamental taste, 461
Swimmerets of crayfish, 106
Sycamore, useful shade tree, 303
Symbiotic root, 251
Sympathetic system, 484
Systemic circulation, 374

Tachina fly, beneficial insect, 75, 82, 85
Tadpole, development of, from egg, 149, 151
 eaten by frogs, 142
 hibernation of, 151
 stage of frog, 140, 147
Tallow, use of, 209
"Tanglefoot," use of, 70
Tanning, use of hemlock bark in, 301
Tapeworm, a common parasite, 119
Tapir, odd-toed ungulate, 194
Tap root, 251
Tar, a product of pine, 301
Tarsus of grasshopper's foot, 58
Tartar, effect on gums, 462
Tassel, staminate flower of corn, 267
Taste, 461, 488
Tea plant, leaves used as beverage, 232
Teeth, an adaption, 19
 of adults, 459, 461
 of fish, 127
 of frog, 142
 of rodents, 191
Temperament, effect of smoking on, 541-544
Temperature, of birds, 164
 of blood, 444
 of fish, 130
 significance of, to man, 412
Tendon, 434
Tendrils, an adaptation, 20, 223, 237
Tent caterpillar, 77
Tentacles of hydra, 322, 323
Terminal bud, 240
Terrapin, use of, as food, 156
Testa developed from integument, 283
Testis, same as sperm, 146
Tests for immunity, 518
Thalamencephalon of frog, 145
Thalessa, parasitic fly, 86
Thallophytes, 317
Thistle, a common weed, 270
Thoracic cavity of man, 427

- Thoracic duct**, 470
Thorax, of grasshopper, 57
Thorns, an adaptation, 242
 of stem, 237
 modified leaves, 223
Thorny locust, modified leaves of, 223
Thousand-legged worms, 116
Throat, of man, 459, 463
 of tadpole, 149
Thrushes protected by law, 169
Thymus gland, 496
Thyroid gland, 496
Thyroxin, 496
Tibia of grasshopper, 58
Tickle-grass, distribution of, by wind, 275
Ticks, harmful insects, 116
Tiger, carnivorous animal, 189
Time, reckoning of, 365-368
 table of geologic, 367
Tissue, definition of, 48
Tissues, of woody stem of dicotyledon, 240
Toad, beneficial animal, 151, 153
 common, 151
 development of, 151
 eats insects and slugs, 151
 enemy of potato beetle, 76
 horned, 157
 life history of common, 151
Toad flax, spur on, 260
Tobacco, effects of use of, 541-544
 inhaling fumes, 542, 543
Tobacco toxemia, 541
Tobacco worm, cocoons of parasite on, 94
Toes, of cows, 199
 varying number of, in animals, 199
Tomato, a food plant, 278
 example of berry, 274
Tomato "worms," larvæ of sphinx moth, 81
Tongue, a sense organ, 488
 of frog, 142
Toothache, result of poor teeth, 463
Toothless mammals, 189
Touch an aid to sight, 491
Toxin, bacterial poison, 340, 347
 of diphtheria, 521
Trachea, of man, 450, 451
Tracheæ, of grasshopper, 59, 62
Trailing stems, 237
Traits of plants inherited, 282
Transient birds, examples of, 161
Transpiration, a factor in moving sap, 231
 amount of water given off by, 230
 defined, 223
 devices for retarding, 229
 discussed, 229
 laboratory work on, 230
 unavoidable, 229
Trapdoor spider, 115, 116
Traps, cause of suffering to animals, 202
 to capture flies, 85
 use of, in controlling insects, 69
Tree crickets, harm done by, 63
Tree plantations injured by rabbits, 193
Tree sparrow, a seed-eater, 168
 at bread crumb station, 184
Trees, able to grow on poor land, 293
 care of, 303
 preferences of, as to locality, 293
 subject to fungal diseases, 304, 306
Tremex borer, harmful insect, 86
Trichinella, 121
Trichinosis, cause of, 121
Trichocysts of paramecium, 333, 334
Trillium, picking of, 272
Trimming trees, 303
Trochanter of grasshopper, 58
Trout, example of bony fish, 125
Trunk mammals, 189
Trunk of elephant, 200, 201
Trunk region, of fish, 125
 of man, 426
Trunks of evergreens, 298
Tuber, 237
Tuberculin test, discovered by Koch, 346
Tuberculosis, a bacterial disease, 511, 512
 in cows, 346
 of throat and other organs, 515
 treatment for, 513, 515
Tubular flowers, 259
Tubular style an adaptation, 265
Tubules of kidney, 455
Tulip tree, 303
Tumors, 510
Turgid cells, 226
Turkeys, domestic birds, 168
Turnip, storage of food in, 255
Turpentine, source of, 301, 307
Turtle, example of Reptilia, 155
 green, use of, as food, 156
 skeleton of, 156
Tusks of elephant, 20

- Tussock moths, 90
 Twining petiole of clematis, 223
 Twining stems, 237
 Tympanic cavity, 493
 Tympanic membrane, 494
 Typhoid fever, a bacterial disease, 511
 inoculations, 519
 spread by carriers, 522
 spread by house fly, 84
 Typhus fever, 82, 526
- Ultra-violet rays, 33
 Umbel, 259
 Underground stems, described, 244
 examples of, 237, 245
 Ungulata, a group of mammals, 189
 Ungulates, 194-197
 Unicellular fungus, yeast an example, 327
 United States Bureau of Fisheries, 138
 Ureter, of frog, 146
 of man, 455
 Urethra, of man, 455
 Urinary bladder of frog, 146
 Urinogenital duct of frog, 146
 Uropod, organ of crayfish, 106
- Vaccination, discussed, 520
 Vacuole, contractile, 331
 food, of ameba, 332
 Valves, of clam shell, 118
 of heart, 446, 448
 of stomach, 464
 of veins, 446
 Variations, in beaks of birds, 163
 in legs of birds, 163
 of animals, 376
 produced by cross-pollination, 267
 Vascular bundles, arrangement of, 235, 238, 239
 conductive system of plants, 225, 231
 of root (conducting vessels), 250
 of woody stems, 240, 241
 Vascular system in plants, 225, 231, 235, 238, 239
 Vegetable ivory, source of, 209
 Vegetable nitrogen, source of, 340, 341
 Vegetable oyster, biennial root, 255
 food of man, 255
 Veins, of leaf, 218, 219
 of man, 446
 Veneer, 306, 307
 Ventral nerve chain of crayfish, 110
 Ventricle (fourth) of brain, 145
- Ventricles of heart, 446, 447
 Venus's-flytrap, 223
 Vermiform appendix, 460, 464
 Vertebræ, 428
 Vertebrates, a group of animals, 124
 Vesper sparrow, food of, 167
 Villi, described, 465
 function of, 468
 Vinegar, a preservative, 345
 Vinegar eel, 120
 Violet, has a spur, 260
 Virus in inoculation, 512
 Vitamins, 29, 30, 474-476
 Vitreous humor, 489
 Vocal cords, location of, 451, 452
 Voice box, 450
 Voluntary muscle cells, 433
 Voluntary muscles, 433
 Volvox, described, 335
 Vultures, beneficial birds, 168
- Walking, correct position of the feet in, 438
 Walls of cells, 46
 Walnut, plant protein in, 466
 Walnut tree, 307
 Walrus, 189
 Ward-McIlheny Bird Preserve, 171
 Warm climate favored by some evergreens, 301
 Warm-blooded animals, 188, 420
 Warmth, a condition of the growth of bacteria, 339
 Warning coloration, 83
 Wasp fly, beneficial insect, 82
 Wasps, example of Hymenoptera, 67
 Waste, poisonous, 456
 removed by excretion, 456
 Waste materials of photosynthesis (by-products), 227
 Water, a necessary condition for growth of bacteria, 339
 composition of, 29
 contains bacteria, 339
 universal solvent, 29
 used by plant, 2
 uses of, in body, 29, 457
 Water beetles, destroyers of mosquitoes, 83
 enemies of tadpoles, 151
 Water fleas caught by hydra, 323
 Water pores, 229
 Water-tiger, larva of water beetle, 133
 Wax, in ear, 494

Wax — Continued

- produced in United States, value of, 99
- Weasels, carnivorous mammal, 190, 191
- Web of flying squirrel, an adaptation, 200
- Webbed toes, of reptiles, an adaptation, 159
 - of swimming birds, 163
- Webs of spiders, 115
- "Wedding flight" of bee, 99
- Weeds, common, list of, 270
 - fought by preventing formation of fruit, 270
 - seeds destroyed by birds, 168
- Weevils, example of beetle, 74
 - injurious insects, 66
- Whale, a marine mammal, 189
 - feelers of, 420
 - lacks hind legs, 199
 - source of oil, 239
- Wheat, a cereal, 277
- Wheat plant, root system of, 253
- Wheatear, migration of, 181
- White blood corpuscles, 443
- White grub, eaten by birds, 74
 - injures skins, 209
- White oak, uses of, 306
- White of the eye, 488
- White pine, value of, 306
- White substance of nerves, 484
- White-breasted nuthatch at feeding station, 184
- Whitefish, example of the bony fish, 125
- Whooping cough, a bacterial disease, 511
 - a contagious disease, 511
- Wigglers, enemies of, 83
 - larvæ of mosquitoes, 83
- Wild boar, ancestor of pig, 194
- Wild cucumber, dispersal of seeds of, 276
- Wild geese, transients, 161
- Wild ox, ancestor of cattle, 195
- Wild plants, improvement of, by man, 8-11
- Willow tree, source of charcoal, 307
 - twigs, rooting of, 244
- Wind-distributed fruits, 275
- Windpipe, 450, 451
- Wind-pollinated flowers, 265
- Wind-pollination, 265
- Wing membrane of bats, 198
- Wings, appendages, 125
 - of birds, 163, 164
 - of fruits, 275
- Winter visitants, examples of, 161

- Wintergreen leaves used for flavor and for medicine, 232
- Wichita National Game Preserve, 170
- Wolf, a carnivorous animal, 189
- Wood, adaptations of, 247
 - formation of, 242
- Wood alcohol, 307
- Wood borers, 74
- Wood pulp, source of, 301
- Wood rays in stem of pine, 299
- Wood wastes utilized, 307
- Woodchuck, destroyed by birds, 167, a rodent, 167, 191
- Woodpeckers, at suet station, 184
 - destroyers of borers, 74
 - destroyers of eggs of insects, 94
 - (downy) permanent residents, 161
 - food of, 176
 - protected by law, 169
- Woody rings in plants, how formed, 239, 299
- Woody stem, structure of, 237, 241
 - use of elements in, 241
- Woody trees examples of dicotyledons, 235
- Woody twig, buds of, 240
- Wool, 196, 197
- Workers (bees), 94, 96, 99
- Worm group, 119
- Worms, food of fish, 127
 - food of frogs, 142
- Wormwood used for medicine, 232, 246
- Wren, destroys larvæ of insects, 94
 - discussed, 180
 - protected by laws, 169
- Xylem, conductor of water, 231
 - in fibrovascular bundles, 223
 - in relation to cambium, 237, 238
- Yarrow, leaves of, 219
- Yeast, 327-329
- Yellow fever, a protozoan disease, 511
 - carried by mosquito (Aedes), 517
- Yellow pine, value of, 306
- Yellow warbler, 180, 181
- Yellowstone National Park, game preserve, 170
- Yellowstone Park Timberland Reserve, 292
- Yolk, of fish's eggs, 131
 - of frog's egg, 149
- Yosemite National Park, game preserve, 170

pedunculate

Q. salicifolia

Q. Rubra

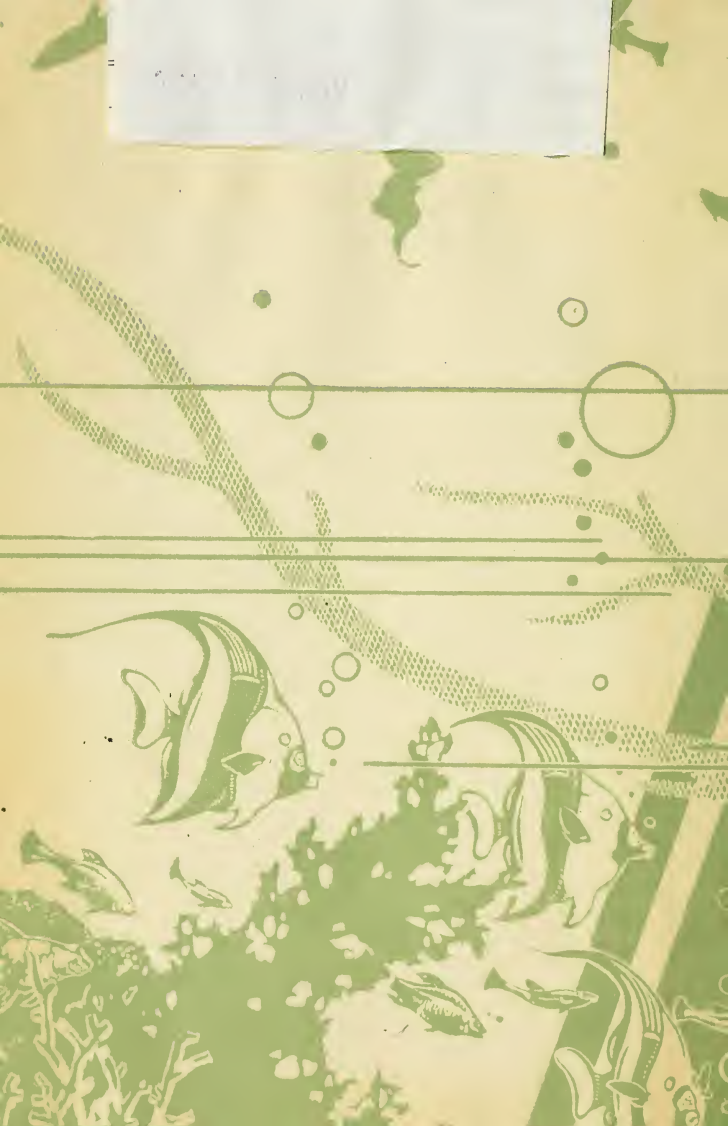
Q. sp. 1

Q. sp. 2

Q. sp. 3

Q. sp. 4

Q. sp. 5



S.C.C.
G.G.C.

phloem
cambium
xylem
epidermal
palisade cell
sclerenchyma

Education
CURRICULUM

626119

QH
308
S63

Smallwood, W. M.
New biology.

COMPACT STORAGE

EDUCATION LIBRARY

CURRICULUM

QH 308 S63 c.1
Smallwood, W. M. (William)
New biology,
CURR



0 0004 8739 296

A10076

